

Technical Study 59e

**Urban Energy  
in Fiji**

A Survey of Suva's Household, Industrial,  
and Commercial Sectors

*Suliana Siwatibau*

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#### ABSTRACT -- RESUMÉ -- RESUMEN

**Abstract --** In many developing countries, such as Fiji, energy planning and energy policy formulation represent a relatively recent phenomenon. Such processes are needed, for example, to develop strategies for substituting imported oil with local energy sources. Before such a process can begin, however, the sources and uses of energy must be known. A survey was, therefore, undertaken of 1011 electrified households, 301 nonelectrified households, 76 industrial establishments, 77 commercial concerns, and 10 large office buildings to determine energy-use patterns in Suva, capital city of Fiji.

Most households in Suva rely on kerosene for their cooking-fuel needs. As income declines, however, reliance on firewood increases. Shrinking supplies of freely available firewood have forced many poorer households to search for other less desirable fuels, such as residues from timber mills. Thus, efforts by the government have been directed to such measures as tree farms and the introduction of safer, fuel-efficient kerosene stoves.

Gasoline for private cars accounts for 38% of total energy consumption by households in Suva. Energy (largely in the form of imported petroleum) could be saved through increased use of the public transport system combined with a public education program.

Suva's industrial sector uses 96% of its energy for production purposes, such as for steam and hot water. Most of this energy comes from coal (77%). Appreciable savings are possible through fuel substitution (notably in boilers), more efficient use of steam and hot water, and improved lighting and refrigeration.

Electricity is used in 15 of 17 end-use categories in Suva's commercial establishments. Air-conditioning (14%) represents the largest single end-use, particularly in large office buildings, followed by refrigeration (13%) and cooking (11%). Liquefied petroleum gas (LPG), kerosene, and wood are also used for cooking by many establishments. Energy savings are possible in air-conditioning, refrigeration, cooking, water heating, and lighting.

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**Resumé --** Dans plusieurs pays en développement comme les îles Fidji, la planification de l'utilisation de l'énergie et la formulation d'une politique énergétique sont des phénomènes récents et nécessaires, par exemple, pour établir des stratégies de remplacement du pétrole importé par des énergies locales. Mais comme il faut d'abord connaître les sources et les utilisations de l'énergie, on fit un sondage de 1011 ménages électrifiés, 301 ménages non électrifiés, 76 établissements industriels, 77 entreprises commerciales et 10 grands immeubles à bureaux pour déterminer le profil de l'utilisation de l'énergie à Suva, la capitale des îles Fidji.

La majorité des ménages de Suva cuisinent au kérosène. Cependant le bois remplace le kérosène chez les ménages à plus faible revenu. La rareté grandissante de bois de feu facile à obtenir a forcé beaucoup de ménages pauvres à se tourner vers d'autres combustibles moins attrayants comme les résidus des scieries. Donc les efforts du gouvernement ont porté sur la création de propriétés forestières de production et la diffusion de fourneaux à kérosène plus sûrs et plus économiques.

L'essence pour les voitures privées représente 38 % de la consommation

d'nergie des mnages à Suva. Il serait cependant possible de rraliser des conomies d'nergie (surtout du ptrole import) en faisant grimper le niveau d'utilisation des transports en commun et en mettant sur pied un programme d'ducation publique.

Le secteur industriel de Suva consacre 96 % de l'nergie qu'il consomme à des activits de production, comme la vapeur et l'eau chaude. Cette nergie provient à 77 % du charbon. D'importantes conomies d'nergie seraient rralises en remplaant le combustible (notamment dans les chaudières), en utilisant plus efficacement la vapeur et l'eau chaude et en amliorant l'clairage et la rfrigration.

L'lectricit se retrouve dans 15 des 17 catgories d'utilisation finale pour les tablissements commerciaux de Suva. La climatisation de l'air (14 %) reprsente, à elle seule, la plus importante utilisation finale, particulirement dans les grands immeubles à bureaux. Viennent ensuite la rfrigration (13 %) et la cuisson des aliments (11 %). Beaucoup d'tablissements se servent aussi de gaz, de ptrole liqufi, de krosene et de bois pour la cuisson des aliments. Il serait possible de faire des conomies d'nergie dans la climatisation de l'air, la rfrigration, la cuisson, le chauffage de l'eau et l'lectricit.

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**Resumen --** En muchos pases en desarrollo, como Fiji, la planificacin energtica y la formulacin de polticas en este campo representan un fenmeno relativamente reciente. Estos procesos son necesarios para desarrollar, por ejemplo, estrategias para la substitucin del aceite importado por fuentes locales de energa. Sin embargo, antes de que tales procesos puedan empezar hay que conocer las fuentes y los usos de la energa. Por tanto, se emprendi una encuesta de 1011 hogares electrificados, 301 hogares no electrificados, 76 establecimientos industriales, 77 firmas comerciales y 10 edificios grandes de oficinas con el fin de determinar los patrones de uso de energa en Suva, la capital de Fiji.

En esta ciudad, la mayora de hogares dependen del queroseno para las necesidades de cocci3n. Pero a medida que los ingresos disminuyen, la dependencia de la lea aumenta. Los suministros decrecientes de lea disponible libremente han obligado a muchos hogares pobres a buscar otras fuentes de combustibles menos deseables, como los residuos de los molinos de madera para fines industriales. Por tanto, los esfuerzos oficiales se han dirigido a medidas tales como fincas productoras de rboles y la introducci3n de estufas de queroseno ms seguras y eficientes en el uso del combustible.

La gasolina para autos particulares llega al 38% del consumo total de energa en los hogares de Suva. Podra ahorrarse energa (en su mayora bajo la forma de petrleo importado) mediante el uso aumentado del sistema de transporte pblico combinado con un programa de educaci3n pblica.

El sector industrial de Suva emplea 96% de su energa en producci3n, por ejemplo en agua caliente y vapor. La mayora de esta energa procede del carb3n (77%). Podra tambin ahorrarse una considerable parte de este, mediante la substituci3n de aceite (especialmente en calderas), el uso ms eficiente de vapor y agua caliente, y la mejora en la iluminaci3n y la refrigeraci3n.

La electricidad se emplea en 15 de las 17 categoras de uso final de los establecimientos comerciales de Suva. El aire acondicionado (14%) representa el mayor uso final individual, especialmente en los edificios grandes de oficinas, seguido por la refrigeraci3n (13%) y la cocci3n (11%). El gas de petrleo licuado (LPG), el queroseno y la madera son tambin usados en muchos establecimientos. Hay tambin posibilidades de ahorro de energa en aire acondicionado, refrigeraci3n, cocci3n, agua caliente y alumbrado.

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## FOREWORD

The importance and significance of energy for growth and development came to the forefront of the policy arena after the first oil price rise in 1973-74, and held its importance after the second price increase in 1978. For oil-importing developing countries, rising oil prices contributed significantly to the unhealthy balance-of-payments situation and triggered a search for ways to reduce their dependency on imported petroleum. Although oil prices have declined recently and have, today, reached levels that were common about a decade ago, most developing countries continue to face severe energy constraints stemming from foreign-exchange shortages and high domestic costs of energy investments (as much as 50% of total domestic public investment in some countries). It is worth noting that, in 1986, oil prices, which continue to dominate all energy options, oscillated over a wide range with the highest level being as much as four times the lowest -- evidence of an unstable international oil market. As a result, energy security remains a priority for most developing countries, with many focusing on substitution for imported petroleum, increasing energy-use efficiencies, and developing locally sustainable and adaptable energy systems.

The oil crisis, normally associated with the modern sector in developing countries, also brought to the world's attention a second, parallel energy crisis. This parallel energy crisis, generally perceived to have affected primarily the traditional sector in developing countries where most people live, has generally been brought about by shrinking supplies of firewood and other forms of biomass energy; which most people in developing countries depend upon to satisfy their basic energy needs. It is now generally recognized that some of the major culprits in the parallel crisis are logging and clearing of land for agricultural purposes, which are often not related to burning firewood for fuel. Regardless of the causes, however, the increasing scarcity of firewood and the associated impacts such as deforestation and soil erosion represent the energy crisis for most people in developing countries. Hence, attention has also focused on ways to increase fuel supplies (e.g., fuelwood farms) or to conserve existing fuel stocks by developing and introducing more efficient small-scale energy conversions and end-use devices (e.g., cookstoves).

For most developing countries, significant energy problems continue to persist, in spite of the recent decline in international oil prices, and are associated mainly with oil and firewood. Before policies such as oil substitution or introduction of more efficient cookstoves can be implemented, we must understand how energy is supplied and used and, in the context of policy formulation and implementation, the importance of the social and cultural milieu has been increasingly recognized. We must understand this milieu if we wish to identify ways to avoid the present energy bottlenecks.

As one step in developing this understanding, IDRC supported Suliana Siwatibau to study urban energy in Fiji, and to generate useful information on how energy is supplied and used. This study complements an earlier one, Rural Energy in Fiji: a survey of domestic rural energy use and potential (IDRC-157e), which was also undertaken by Siwatibau. This support recognized that it was important that the researchers should be able to understand and appreciate the social and cultural milieu of Fiji; of which this team of researchers had a comparative advantage. The study also allowed Fijians to develop the skills and generate the information and policies needed to solve their own problems. It is particularly noteworthy that the findings from this study are already being used in national planning by the Government of Fiji, and savings have been realized as a result of energy conservation programs implemented on the basis of the study's recommendations.

Hartmut Krugmann and Warren Wong

Program Officers

Social Sciences Division, IDRC

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I am grateful for the opportunity to be involved in this study and for the valuable contributions of so many colleagues and friends, without whom the task would not have been achieved. I offer special thanks to:

- Mr James Fricker, assistant survey leader, and Mr Thomas Droz, who developed the computer program and processed the data for the domestic sector survey.
- Mr Eremasi Tamanisau, Mr Tevita Lala and Mr Satya Prakash, who were such industrious and willing survey leaders.
- The students of the University of the South Pacific and Fiji Institute of Technology who were such effective surveyors (they are listed in the appendix).
- The householders who agreed to be surveyed, many of whom prepared delicacies and meals to welcome our surveyors.
- The management and staff of all the industrial and commercial establishments and the offices that we visited to collect our data, for their courtesy in response to our requests and queries.
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- And to the many others I cannot mention here for their kindness during the survey.

Suliana Siwatibau

Survey leader  
Suva, Fiji



## EXECUTIVE SUMMARY

This study was undertaken to analyze the use of energy in the household, industrial, and commercial sectors of urban Suva. It involved surveys of 1011 electrified households, 301 nonelectrified households, 76 industrial establishments, 77 commercial concerns, and 10 large office buildings. The surveys included questionnaire-based interviews, examination of premises, and the study of the records of consumption maintained by users and suppliers of energy.

For householders, transport was found to be the most important single use of energy (38% of total demand). On average, each household used each week 3.99 L of bus diesel fuel, 2.21 L of taxi gasoline, and 22.69 L of private car gasoline. Consumption of private car gasoline was closely correlated ( $r = 0.97$ ) with household cash income. Studies of the per-capita use of transport energy elsewhere suggest transport energy could be reduced in Suva.

Household cooking accounted for 36% of total household energy demand. Of the principal fuels, 400 mL kerosene was used for each meal prepared with it and 2.1 kg wood was used for each meal prepared with it. When wood was used, it was nearly always as an open fire; kerosene was most commonly used with the multiwick burner, which has been shown in tests to have a heat-use efficiency of 49.6%. Use of liquefied petroleum gas (LPG) and electricity was largely confined to higher-income homes. Cost per meal was 2 ¢ for wood, 16 ¢ for kerosene, 30 ¢ for LPG, or 55 ¢ for electricity.<sup>1</sup>

The chief domestic uses for electricity were for refrigeration (45%), lighting (15%), cooking (12%), and water heating (12%). The efficiency of refrigerators was found to differ widely, ranging from 140 to 200 kWh/m<sup>3</sup> per month. In general, consumers of electricity in Suva are not aware of the domestic energy savings available to them.

The survey showed that most industrial establishments employ fewer than 50 people. Electricity was the fuel for the largest number of industrial uses -- lighting, air-conditioning, cooling and refrigeration, hot air and water, steam, chemical processes, mechanical work, on-site transport of goods and office and ancillary purposes -- but it accounted for only 6% of total industrial demand. There were wide variations in the use of electric lighting (0.2-185 kWh/m<sup>2</sup> per year) and air conditioning (5.1-664 kWh/m<sup>2</sup> per year). However, most of the energy used by Suva's industries is for production purposes,

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<sup>1</sup> Cents are in Fijian currency. In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

which account for 96% of demand. Coal provides 77% of energy used in industry; energy is also derived from industrial fuel oil, diesel oil, automotive diesel, waste oil, gasoline, wood, kerosene, LPG, oxyacetylene, and premix (a 50 : 1 mix of gasoline and oil for two-stroke motors).

Appreciable savings in industrial energy would be possible through better lighting arrangements, more efficient refrigeration, better use of steam and hot water, and fuel substitution (notably in boilers).

Suva's commercial establishments also make wide use of electricity, which is so versatile that it is used in 15 of 17 end-use categories surveyed. Electricity accounts for 46% of the total energy demand of the Suva commercial sector. Refrigeration accounted for almost 13% of total energy use and 27% of electricity use. Cooking accounted for 11%, fuels used being LPG, kerosene, electricity, and wood. The largest single use of energy, 14% of total demand, was for air-conditioning. Energy savings would be possible in lighting, refrigeration, air-conditioning, cooking, and water heating.

The survey of 10 large office buildings showed that air-conditioning accounted for 64% of energy. Other uses for energy were lighting, equipment, and elevators.

The people of the Suva urban area can make better use of available energy and save foreign exchange on imported fuels. On the basis of the survey, I would make the following eight recommendations.

- The use of energy in public transport should be examined in detail and measures to improve the efficiency of energy use should be identified.
- Ways of saving transport energy should be publicized.
- Ways of saving domestic energy should be publicized.
- If possible, more efficient kerosene cookers should be developed.
- A program should be promoted in urban areas to improve the use of wood and charcoal in stoves.
- The supply of and likely demand for wood by the different sectors in urban areas should be studied.
- Energy auditing services should be made more readily available to the industrial and commercial sectors of Suva to assist them with energy management.
- Government programs should be devised to help industrial and commercial establishments, especially small ones, introduce energy-saving measures.

## INTRODUCTION: THE NEED FOR THE STUDY

Toward the end of 1977, the Fiji government commissioned a 1-year study of the use of household energy in rural Fiji. It was funded by the International Development Research Centre (IDRC) of Canada and conducted by the author of this study under the auspices of the University of the South Pacific (Siwatibau 1981).

The study made available for the first time to decision-makers comprehensive information on the use of energy by rural householders in Fiji and on the relationship between their use of energy and their socioeconomic status. It also, for the first time, quantified the use of energy not only from commercial sources, but also from noncommercial sources in rural Fiji.

After completion of the rural domestic-energy study, it became evident that a clearer picture of urban energy use was urgently needed. This would give planners and policymakers a better perspective of the national situation. Accordingly, the Fiji government approached IDRC for funding for an urban study that would be a sequel to the rural study.

This second study was first conceived as covering all sectors -- household, commercial, industrial, public, and transport -- of the urban economy in Suva. Unfortunately, time and funding permitted only the first three sectors to be investigated.

At the same time, a similar study was commissioned at the second largest urban centre in Fiji -- Lautoka/Nadi -- by the Fiji government with aid from Australia. It was conducted by the University of the South Pacific. The results of both studies have been valuable in establishing an accurate picture of energy demand in urban Fiji.

The findings of the study reported here are already being used in national planning, and the Fiji government is acting on most of the recommendations.

## THE DOMESTIC USE OF ENERGY

The area covered in this study is the Suva urban area as defined by the Fiji Bureau of Statistics (BOS). The study area consists of Suva City and the outlying area that the BOS calls the Suva peri-urban area. The 1976 national census reported 11,645 private households in Suva City and 8897 in the peri-urban area for a total of 20,542. By the time of this survey, mid-1982, BOS had estimated the population of Suva City to be 13,150 households. There was no BOS estimation of the population of the Suva peri-urban area, but the bureau had estimated that urban households in Fiji had grown since the census by 5.43% per year. Applying this figure to the whole of the Suva urban area, we estimated it contained 28,656 households by mid-1982. Clearly, most of the growth had taken place in the suburbs.

The number of these households that are electrified is not readily available, inasmuch as the Fiji Electricity Authority (FEA) does not use the same boundary lines as the BOS, except for Suva City. The FEA recognizes three regions within the area of our study -- Suva City, Suva suburbs (all of which is within our study area), and Suva rural, which includes the remainder of our study area but also extends beyond it (Fig. 1). For the purposes of this study, we have assumed that half the domestic meters in the FEA's Suva rural area come within our study area. Preliminary investigation thus established that Suva City had 12,885 domestic meters and the outlying Suva area had 6124 meters for a total of 19,009. As each 12 dwellings include on average 13 households, this gives a total of 20,593 electrified households, or 72% of all households in the Suva urban area. Within the city, only 518 dwellings containing 561 households (4%) were not electrified. Throughout the Suva urban area, we estimated 8063 households were nonelectrified; of these, 3801 were squatter households<sup>1</sup>; some nonelectrified households were those of small market-gardeners living outside squatter settlements.

Obviously, nonelectrified households were more numerous outside Suva City, but FEA advises that most expansion of domestic electricity service has been in the outlying and rural areas. The authority states that electrification has been increasing in Fiji urban areas by an average 100 households per month.

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<sup>1</sup> Defined by the Fiji Town and Country Planning Department as nonapproved housing -- that is, housing that is neither on owner-occupied land nor owned by the government housing authority. The land on which squatters settle may be either native-owned, freehold, or crown, and they have a variety of arrangements with the landowners -- from relying solely on the goodwill of landlords to paying regular rent in cash or kind. The houses range from flat-roofed, single-room thatched or corrugated iron sheds to spacious three- or four-bedroom concrete homes.

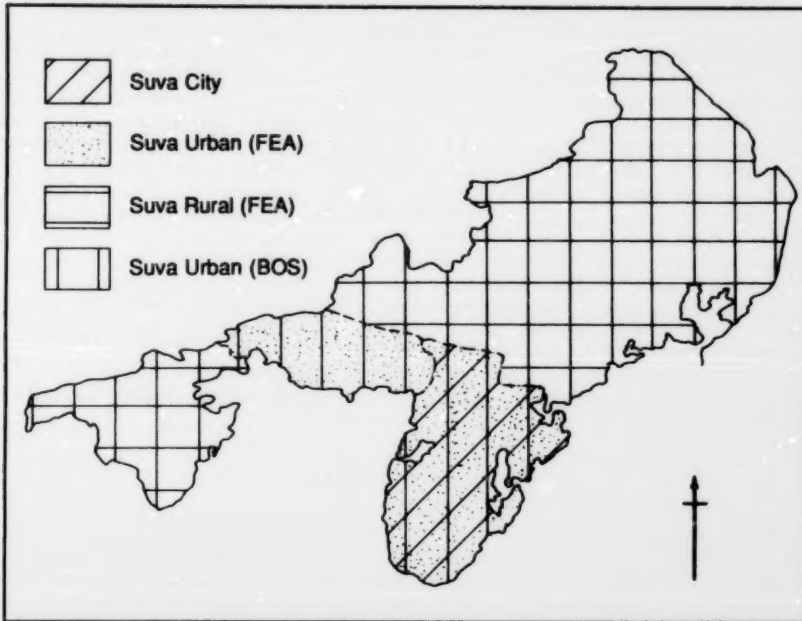


Fig. 1. Suva urban area showing Bureau of Statistics boundaries and rural-urban divisions of Fiji Electric Authority.

According to the 1976 census, the ethnic origins of the population of the study area were 45.3% Indian, 41.0% indigenous Fijian, 3.6% part-European, 2.6% pure European, 2.3% Chinese or part-Chinese, 2.3% Rotumans, 2.4% other Pacific islanders, and 0.5% all others.

The survey was intended to identify the major sources and amounts of energy used in households, clarify the socioeconomic factors associated with each type of energy use, identify possibilities for conservation and to learn the practices, preferences, and perceptions of the people in the area with regard to sources and uses of energy with a view to assisting policy decisions.

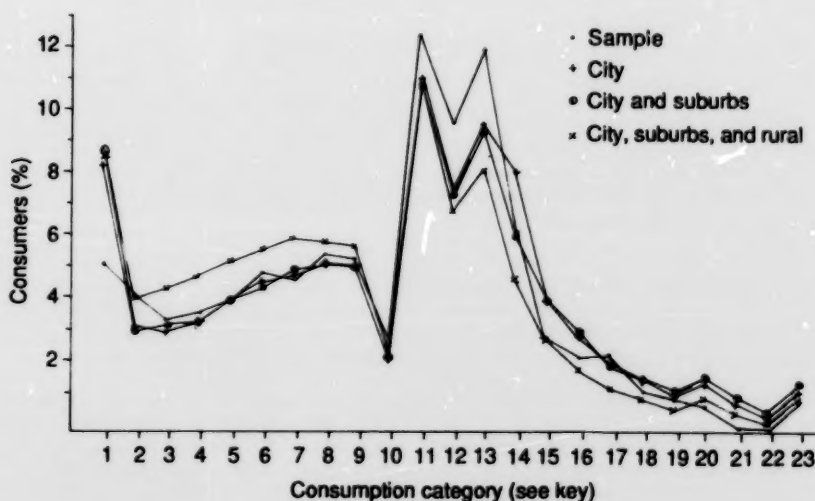
#### Methods

We originally intended to cover a 10% sample of electrified and nonelectrified households in the study area. This proved beyond our resources; furthermore, rigorous rejection criteria built into the questionnaire led to a reduction in the sample of electrified and nonelectrified households on which the final analysis was based.

We selected every 10th domestic meter in the area that the FEA calls Suva City, Suva suburbs, and part of the more densely populated Suva rural (this does not, in fact, cover all of the study area) for a total of 1712 meters. Each meter selected served a single household.

Several months elapsed between selection and survey, as the project required the use of university students as surveyors during their short mid-semester break. When the survey was finally undertaken, the sample represented 8.1% of the total domestic meters of Suva City and suburbs. Some of the sample was rejected during the survey process, and the final sample on which this report is based was 1011 electrified households, which formed 7.0% of the electrified households in Suva City and suburbs or 4.1% of those in the whole study area.

Analysis of electricity consumption during September 1981 (the latest month available at the time of the survey) shows that the sample slightly underrepresents the very low and the very high consumption bands but in overall distribution is reasonably representative (Fig. 2). The average monthly bills in that month for electricity of the various groups shown were: Suva City, FJD 22.57; Suva suburban, FJD 28.23; and Suva rural, FJD 12.51. Of the households in our survey, FEA records for February 1982 showed billings of FJD 21.88; our questionnaires in June 1982 indicated average billings of FJD 21.95.

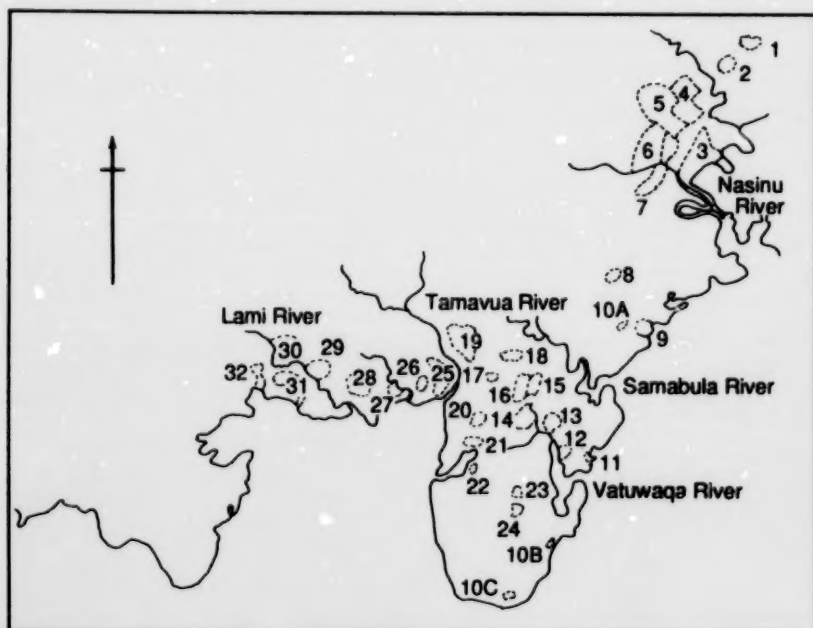


| Category | KWh/month | Category | KWh/month | Category | KWh/month |
|----------|-----------|----------|-----------|----------|-----------|
| 1        | 0-15      | 9        | 86-95     | 17       | 351-400   |
| 2        | 16-25     | 10       | 96-100    | 18       | 401-450   |
| 3        | 26-35     | 11       | 101-125   | 19       | 451-500   |
| 4        | 36-45     | 12       | 126-150   | 20       | 501-600   |
| 5        | 46-55     | 13       | 151-200   | 21       | 601-700   |
| 6        | 56-65     | 14       | 201-250   | 22       | 701-800   |
| 7        | 66-75     | 15       | 251-300   | 23       | >800      |
| 8        | 76-85     | 16       | 301-350   |          |           |

Fig. 2. Distribution by bands of consumption per month in electrified homes in Suva.

The nonelectrified households were more difficult to enumerate and select. It was thought that squatter settlements were more likely to contain nonelectrified homes. We visited all the known squatter areas within the study area (Fig. 3) and recorded all electrified and nonelectrified dwellings in them. We visited and surveyed every 10th nonelectrified home in each settlement, a total of 318. Of the survey reports, 17 were rejected and the final sample of 301 represents 7.9% of the squatter households and 3.7% of all nonelectrified households in the study area. Because of the simpler lifestyle, the sample of nonelectrified households may be assumed representative of all such households in the study area.

The final questionnaire used was the result of an iterative process. The first questionnaire was tested by a 10-student team on a



- |                               |                       |                              |
|-------------------------------|-----------------------|------------------------------|
| 1 Naulu and Chadwick          | 11 Vatuwaqa           | 23 Malekuli                  |
| 2 Bangladesh                  | 12 Lemaki             | 24 Tutaleva                  |
| 3 Rampuna/Narere              | 13 Sukhu Estate       | 25 Nadonumai/<br>Delainavesi |
| 4 Makoi                       | 14 Jifitu             | 26 Navesi                    |
| 5 Tovata/Pritam Singh Road    | 15 Muslim League      | 27 Vugalei/Maidina           |
| 6 Tovata                      | 16 Deq Dutt Estate    | 28 Lami Village              |
| 7 Kalabo                      | 17 Lovoni Road        | 29 Matata                    |
| 8 Nasinu/Caubati              | 18 North of Mead Road | 30 Qauia Village             |
| 9 Kinoia Village              | 19 Tamavua-i-Wai      | 31 Naivikinikini             |
| 10 A, B, C.                   | 20 Valenimanumanu     | 32 Kalekana                  |
| Laucala Beach/<br>Laucala Bay | 21 Nauluvatu          |                              |
|                               | 22 Kai Ra             |                              |

Fig. 3. Suva urban area, showing location of squatter settlements.

stratified sample of 87 electrified households. The project showed that some questions were ambiguous, inconsistent, or irrelevant and that the surveyors needed better training. A second, revised questionnaire was tested by four students on 49 households at a government police-housing development in Suva City. A third, revised questionnaire was used for the survey reported here; this was held in the midyear university break, 5 July to 6 August 1982.

The questionnaire was designed to elicit information about type and ownership of the dwelling, the use and cost of various fuels and appliances for cooking, refrigeration, lighting, and heating water, the use of various transport modes by each member of the household, the racial origin of the head of the household, the number of people in the household, and after-tax income.

A group of 27 university students was used to collect the data; they were selected by a simple written test and an interview. They received 1 week of training before beginning the field work. The data were collected in an interview, the basis of which was the questionnaire -- surveyors were encouraged to be as informal as possible (Fig. 4).

In electrified homes, surveyors filled in an extra data sheet that listed electrical appliances, their ratings, and the time each was used. It was not possible to actually measure the energy used (this would have required regular measurements over a period); however, in selected homes meters were attached to refrigerators and hot-water heaters and a simple questionnaire recorded the amount of



Fig. 4. Student surveyor interviewing family in domestic survey.

electricity used, the make and model of the appliance, and the length of time it was operating.

In addition, the assistant project leader carried out tests in selected homes to determine the efficiency of electric irons and stoves.

Statistical analysis of the electricity bills of surveyed households, against the background of the various appliances reported in each, made it possible to estimate the average fuel costs of each type of appliance.

Finally, surveyors noted the rating of each appliance and asked how many hours it was in use; thus they were able to estimate its overall power consumption.

In nonelectrified homes, surveyors asked householders to put aside a pile of wood large enough to cook either one meal or all the meals for a day. They then weighed the wood on a spring balance with an accuracy of 0.05 kg. They noted different species of wood in the pile and retained a sample to analyze it for moisture. If the householder had no wood available, the surveyor left the answer space blank.

The surveyors assessed the use of kerosene in nonelectrified homes by carrying a 4.5-L can of kerosene and a cylinder that could measure up to 100 mL. At each home, they measured the amount of kerosene that would fill each appliance and then asked how many meals such an amount would cook or (if for lighting) how many hours it would last. The surveyors usually gave the householders 1 L of kerosene each as a gesture of appreciation for their cooperation.

## Results

Household incomes in Suva are higher than the national levels (Fig. 5) reflecting the widening gap between urban and rural incomes. For nonelectrified households in the Suva, distribution of incomes is similar to the national one.

The income of a household determines the access of its members to housing, nutrition, health care, education, and recreation. Consumption of these necessities entails the use of energy. Consequently, it is not surprising that patterns of energy use correspond to those of household income.

Most Suva nonelectrified households live in flat-roofed dwellings made of flat or corrugated iron. Wooden walls and iron roofs are popular: there are a few concrete walls. Poor households near the bush often use grass or bamboo as a building material. In nonelectrified homes, metal was the material for 60.1% of walls, wood 32.9%, grass or bamboo 4.3%, and masonry or concrete 2.7%.

Among Suva's electrified households, 51.1% were owner-occupied (Table 1), 35.9% being single units and 15.2% being apartments. In this category, 77.2% of walls were concrete, 19.4% wood, and 3.4% metal.

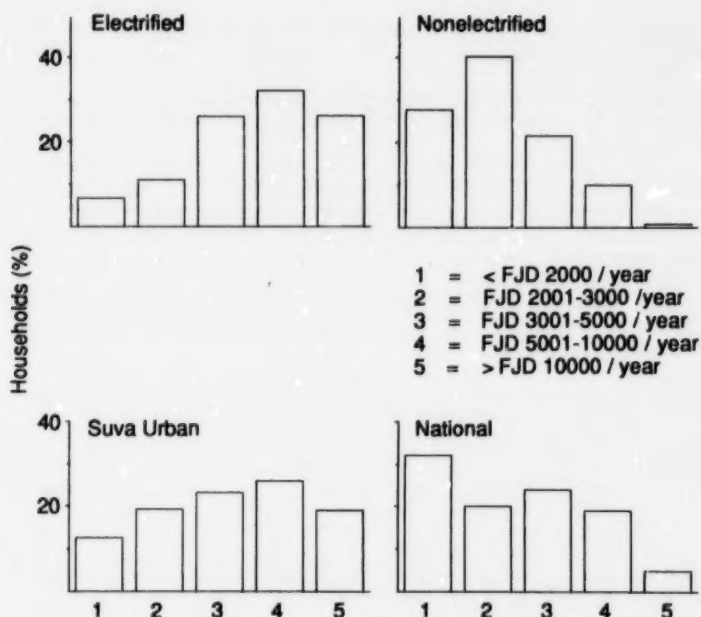


Fig. 5. Income distribution in surveyed electrified and nonelectrified households and nationally (1977 Bureau of Statistics survey). In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

The average family of 5.8 people occupied  $39.4 \text{ m}^2$ , which is greater than the Fiji public health stipulation of  $5.68 \text{ m}^2$  per adult and  $3.78 \text{ m}^2$  per child. Electrified households averaged 5.49 persons, nonelectrified households averaged 5.84 persons, and the average for the total survey population was 5.57.

At the time of the survey, 6% of nonelectrified households had no income earners and relied for support on help, in money or kind, from relatives and neighbours (Fig. 6). A small number were on government welfare schemes. Not surprisingly, households with higher incomes tended to have more earners and fewer dependents (Fig. 7). Thus the higher-income electrified households averaged more income-earners (1.76 vs 1.26) than nonelectrified households, fewer persons per household (5.49 vs 5.84), and fewer persons under 16 (1.88 vs 2.52).

The survey also recorded the race of the head of each household, although it should be noted that this does not necessarily indicate the race of all members of a household, because of mixed marriages and live-in domestics. Thus, there is no certain way of determining how representative our sample was of the various racial groups.

Of the electrified households, 28.8% were headed by native Fijians, Rotumans, or other Pacific islanders; 59.0% by Fijians of Indian descent or origin; and 12.2% by those whose racial origin was

Table 1. Percentage distribution of different types of electrified housing by income groups.<sup>a</sup>

| Annual household cash income (FJD) <sup>b</sup> | Housing authority | Rented | Occupant owned | Other |
|-------------------------------------------------|-------------------|--------|----------------|-------|
| <1000                                           | 51.6              | 19.4   | 25.8           | 3.2   |
| 1501-2000                                       | 37.2              | 5.7    | 51.4           | 5.7   |
| 2001-3000                                       | 27.6              | 20.6   | 45.6           | 6.3   |
| 3001-5000                                       | 25.5              | 25.1   | 48.1           | 1.2   |
| 5001-10000                                      | 19.4              | 30.8   | 49.8           | 0.0   |
| >10000                                          | 6.4               | 32.8   | 60.7           | 0.0   |
| All electrified                                 | 19.9              | 27.6   | 51.1           | 1.3   |

<sup>a</sup> Totals may not add to 100 because of rounding.

<sup>b</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

Chinese, European, or other or a mixture of these and Fijian. For nonelectrified households, the equivalent values were 65.8, 33.9, and 0.3%. We refer to these groups as Fijian, Indo-Fijian, and "other," because analysis has shown that each group has a distinct cultural pattern. For instance, Fijians have stronger extended family links than "others" and thus tend to have households with more than the nuclear family; they averaged 5.77 persons per household, 2.24 under 16, and 1.78 income earners. Indo-Fijians averaged 5.49 persons per household, 1.78 under 16, and 1.78 income earners. "Others" averaged 4.79 persons per household, 1.54 under 16, and 1.66 income earners.

Of the three sociocultural groups, 51.6% of Fijian households earned more than FJD 5000/year, against 56.1% of Indo-Fijian, and 85.4% of "others." Only 18.6% of Fijian households earned more than FJD 10,000 against 23.6% of Indo-Fijian and 56.9% of "others." Fijian households averaged yearly cash incomes of FJD 6723 (FJD 1165 per person) against FJD 7415 (FJD 1350 per person) for Indo-Fijian households and FJD 11,582 (FJD 2419 per person) for "others."

As cash income determines the purchasing power of a household, it is not surprising that home ownership, types of cooking fuel used, and the range of appliances available largely reflected income distribution, which in turn was strongly associated with cultural grouping.

In housing, 42.2% of Fijians lived in housing authority dwellings, 31.3% in other rented accommodation, 26.1% in owner-occupied homes, and 0.3% in some other form of accommodation. Among the Indo-Fijian group, 11.4% lived in housing authority dwellings, 20.5% in other rental accommodation, 66.2% in owner-occupied homes, and 2% in other types of accommodation. Among "others," 9.0% had housing authority accommodation, 53.6% had other rental accommodation, and 37.4% owned their own dwellings. Thus, Fijians are more likely to live in housing authority dwellings, Indo-Fijians are more likely to own their own homes, and "others" are more likely to rent. Nonelectrified householders are mostly squatters.

### Cooking fuels

The survey showed that the most frequently used cooking fuel is kerosene, both in electrified and nonelectrified households, although

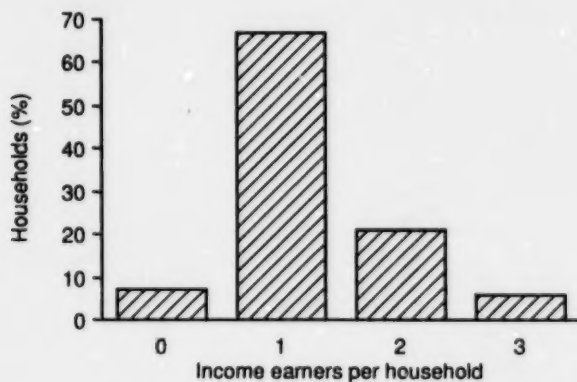


Fig. 6. Distribution of income earners per household.

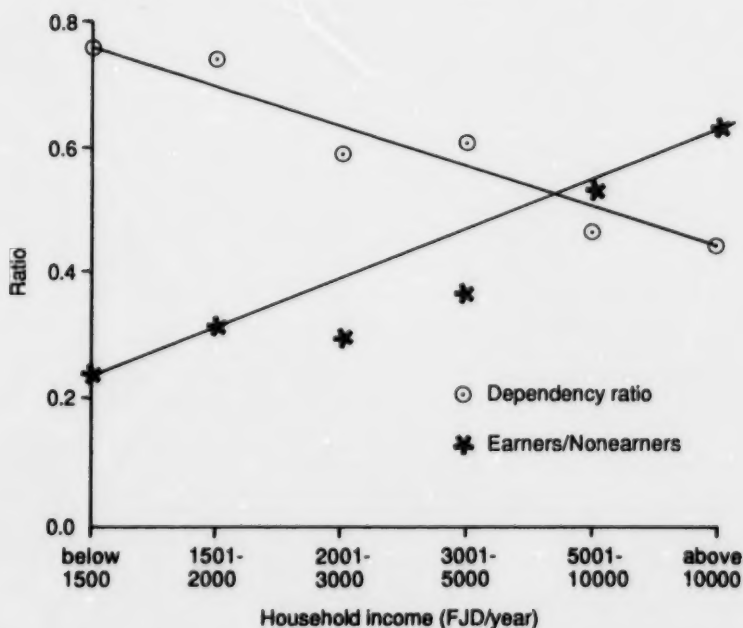


Fig. 7. Variation with income of dependency ratio and proportion of earners to nonearners. In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

most households use more than one fuel, taking advantage of what is available (Fig. 8). Kerosene is popular because it is the cheapest commercial fuel, is easy to buy in small quantities, and is cleaner and faster than wood. Families that normally cook with wood keep kerosene for breakfasts and quick meals and for rainy days when dry wood is not easy to find.

Of the 77% of Suva's households that use kerosene for some if not all their cooking, fully 82% do so using a multiwick single-burner cooker, which is by far the cheapest type of cooker available and seems to be the most fuel-efficient. The second most popular kerosene cooker is the Primus pressure stove.

A survey of retail prices in Suva shops showed that multiwick single-burner round cookers ranged from FJD 6.30-11.50 for small cookers (10-14 wicks) and to FJD 23 for large ones (20 wicks). Square multiwick cookers were FJD 11.00-14.20 for small ones and FJD 11.90-16.30 for medium ones (16 wicks). Replacement wicks were 21 ¢.

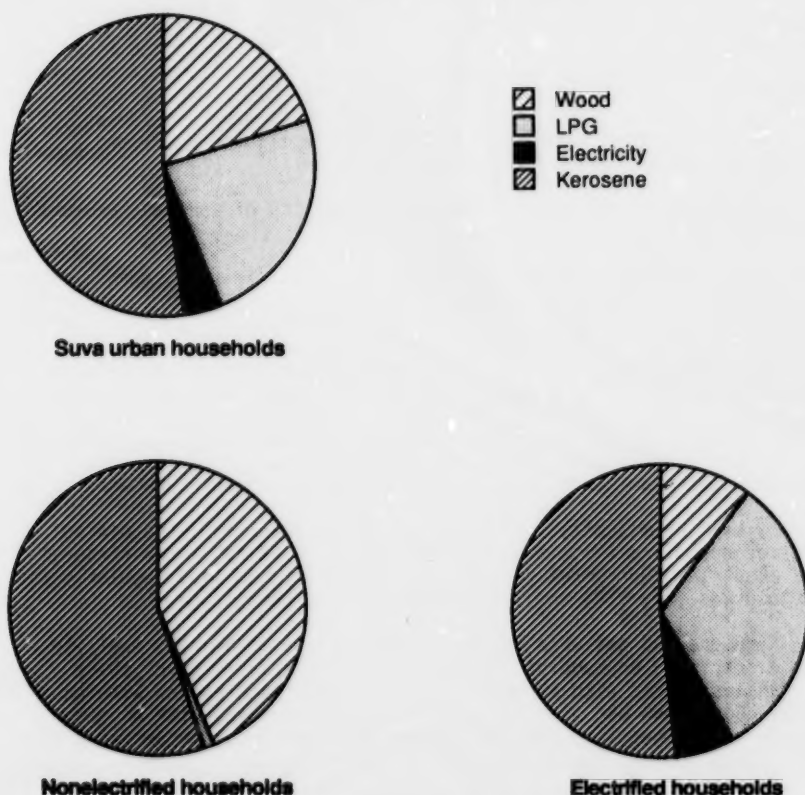


Fig. 8. Frequency of use of different cooking fuels in an average household.

Of the single-wick types with a glass bowl, small ones with a single burner were FJD 26.40-34.00 with replacement wicks at 99 ¢. Double burner medium types were FJD 39.30-50.30 and large types with three burners were FJD 73.60-87.00 (replacement wicks for medium and large types were FJD 2.40).

Primus pressure stoves retailed for FJD 9.20-30.40 (small), FJD 58.00 (medium), and FJD 98.40-142.00 (large).

Tests in previous studies on the relative efficiency of multiwick and Primus pressure stoves do not yield consistent results; however, our survey of nonelectrified households indicated that those that used a multiwick single burner cooker averaged 600 mL kerosene per meal, those that used a double burner averaged 710 mL, and those that used a Primus pressure stove averaged 910 mL.

In tests in 1976, the New Zealand Consumer Council recommended as safe only 4 of 13 common kerosene cookers examined. These included three types of glass-bowl burners and the Primus pressure cooker, which was the least fuel-efficient, although cheaper to buy. The Council did not rate any of the multiwick burners. From January 1978 to October 1983, the Suva Fire Safety Division attributed 36 fires to problems with multiwick kerosene cookers. Of these, 10 occurred when flame flared, burning surrounding combustibles, 10 were recorded as "accidental," 9 were the result of explosions, 3 happened during unattended cooking, 3 during refilling with a lighted wick, and 1 resulted from a flashback on reignition.

There are no reliable data on the durability of various kerosene cookers. Wicks last an average 3.03 months.

Other families used LPG (bottled gas) or electricity because these fuels were even cleaner and more convenient, as for instance when used to heat an oven for baking.

Most nonelectrified households (65%) used a combination of wood and kerosene, which is cheaper than using kerosene only (Table 2). It appears, however, that those households used the two fuels less efficiently than did households that used only one fuel, as indicated by the figures for energy used per person per meal. Furthermore, larger households tended to use wood, and smaller ones kerosene.

By far the majority (59%) of those who cooked with wood did so over an open fire (Fig. 9), 11% used some kind of home-made burner, and about 1% used commercial stoves. About 6% used wood regularly for earth ovens (Fig. 10) and 3% used it only for barbecuing.

Kerosene and gas were the most frequently used cooking fuels in the electrified households (Table 3). A little over 25% of these households cooked with kerosene only, and about 16% cooked with gas only. For those who used two cooking fuels, kerosene with wood or kerosene with gas were the most popular combinations. Households that used three cooking fuels were less frequent.

We were not able to monitor precisely the amount of fuel used for each meal; however, it was possible to make a fairly accurate assessment of the use of LPG because the gas is delivered in standard 13-kg cylinders and most people remembered how long a cylinder lasted. The

Table 2. Cooking fuels of nonelectrified households.

| Fuels <sup>a</sup>       | % of all households | Average size of household | Meals/year per household | Total fuel/year per household (kg or L) | Fuel cost/household (FJD) <sup>b</sup> | Fuel use/person per meal |             |
|--------------------------|---------------------|---------------------------|--------------------------|-----------------------------------------|----------------------------------------|--------------------------|-------------|
|                          |                     |                           |                          |                                         |                                        | Cost (t)                 | Energy (MJ) |
| Single fuel              |                     |                           |                          |                                         |                                        |                          |             |
| Wood (open fire)         | 11.0                | 6.71                      | 1081                     | 2309                                    | 24.00<br>(3.58) <sup>c</sup>           | 0.3                      | 6.1         |
| Wood (stove)             | 1.3                 | 3.75                      | 1092                     | 1321                                    | 14.00<br>(3.73)                        | 0.3                      | 6.3         |
| Kerosene                 | 22.0                | 4.73                      | 1059                     | 291                                     | 155.00<br>(32.77)                      | 3.0                      | 2.1         |
| Two fuels                |                     |                           |                          |                                         |                                        |                          |             |
| Wood/kerosene            | 65.0                | 6.05                      | 566                      | 1090                                    | 12.00                                  | 0.4                      | 6.2         |
| Total                    |                     |                           | 539                      | 239                                     | 133.00                                 | 4.0                      | 2.7         |
| Mean                     |                     |                           |                          |                                         | 145.00                                 | 3.6                      | 4.5         |
| Three fuels <sup>d</sup> | 0.7                 |                           |                          |                                         |                                        |                          |             |
| Wood/kerosene/LPG        |                     |                           | 639                      | -                                       | -                                      | -                        | -           |
|                          |                     |                           | 326                      |                                         |                                        |                          |             |
|                          |                     |                           | 128                      |                                         |                                        |                          |             |

<sup>a</sup> Wood measurement quoted is equivalent oven dry weight.<sup>b</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).<sup>c</sup> Value in parentheses is cost per person.<sup>d</sup> Sample too small for meaningful data.

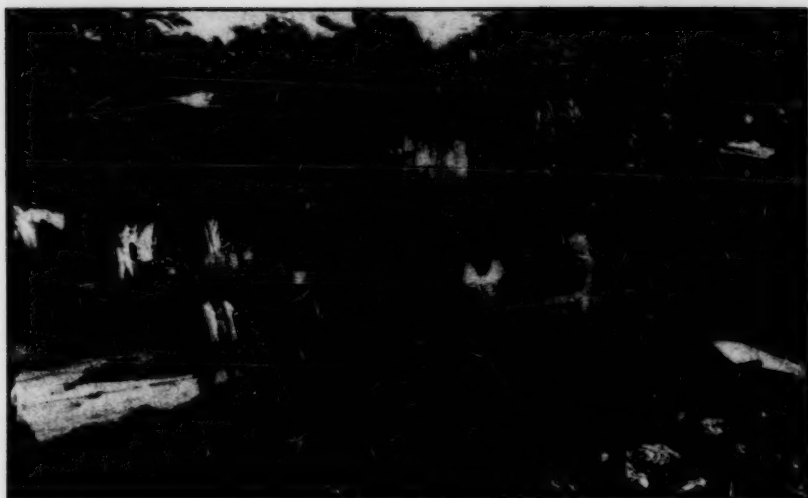


Fig. 9. Use of wood in an earth oven.

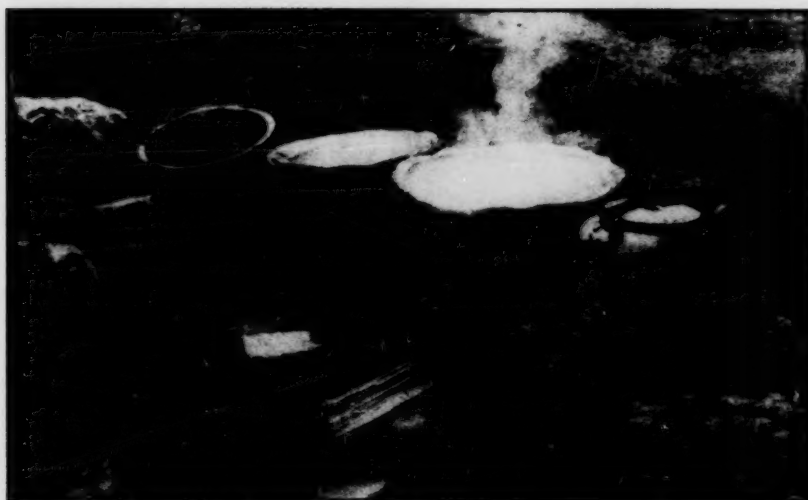


Fig. 10. Cooking with wood over an open fire: the most common cooking method in nonelectrified households.

amount of gas used for each meal differed with the different combinations, but the use of gas was not necessarily lower in combination with another fuel than it was as a single fuel. Consumption was no doubt influenced more by the size of the family and the type of

Table 3. Cooking fuels of electrified households.

| Cooking fuel combinations | Households (%) | Meals per year by fuel |       |       |             |
|---------------------------|----------------|------------------------|-------|-------|-------------|
|                           |                | Kerosene               | Wood  | Gas   | Electricity |
| Single fuels              |                |                        |       |       |             |
| Kerosene                  | 25             | 1007.6                 | -     | -     | -           |
| Wood                      | 1              | -                      | 941.2 | -     | -           |
| Gas                       | 16             | -                      | -     | 927.0 | -           |
| Electricity               | 2              | -                      | -     | -     | 844.1       |
| Two fuels                 |                |                        |       |       |             |
| Kerosene/wood             | 17             | 758.1                  | 380.8 | -     | -           |
| Kerosene/gas              | 13             | 574.7                  | -     | 616.2 | -           |
| Kerosene/electricity      | 3              | 799.3                  | -     | -     | 385.7       |
| Wood/gas                  | 3              | -                      | 317.8 | 755.5 | -           |
| Wood/electricity          | 1              | -                      | 601.5 | -     | 440.3       |
| Gas/electricity           | 6              | -                      | -     | 888.4 | 223.2       |
| Three fuels               |                |                        |       |       |             |
| Kerosene/wood/gas         | 5              | 559.1                  | 227.3 | 471.2 | -           |
| Kerosene/wood/electricity | 2              | 839.4                  | 154.0 | -     | 239.1       |
| Kerosene/gas/electricity  | 2              | 446.3                  | -     | 590.6 | 147.1       |
| Wood/gas/electricity      | 1              | -                      | 208.8 | 868.0 | 52.2        |
| All four fuels            | 4              | -a                     | -a    | -a    | -a          |

a Information not extracted.

cooking -- for instance, baking uses more fuel than quick frying. Indeed, the survey showed that households that used gas only for cooking actually used less gas (95.89 kg/year or 0.103 kg/meal) than households that combined the use of gas with the use of other fuels. Households that combined gas with kerosene used 102.8 kg/year (0.167 kg/meal), with wood 125.5 kg/year (0.166 kg/meal), with electricity 108.4 kg/year (0.122 kg/meal), with kerosene and wood 96.3 kg/year (0.204 kg/meal), with kerosene and electricity 124.8 kg/year (0.214 kg/meal), and with wood and electricity 114.6 kg/year (0.132 kg/meal).

We also learned that although 21.3% of electrified households have electric stoves, only 19% ever used them and only 2.6% used electricity as the exclusive cooking energy source. This makes sense in that electricity is by far the most expensive cooking energy source -- we established that householders averaged 3.67 kWh per meal (equivalent to 13.21 MJ or 2.41 MJ/person). At 15.00 ¢/kWh, the cost per meal was 55.05 ¢. By contrast, the next most costly fuel, gas, averaged 0.289 kg/meal (14.45 MJ or 2.63 MJ/person) at a cost per meal of 29.75 ¢. Kerosene, at 0.381 L/meal (13.98 MJ or 2.55 MJ/person), cost 16.00 ¢/meal. Wood was the cheapest fuel: it was usually free, but, at market prices, the average use of 2.065 kg (dry weight) cost 2.41 ¢/meal. The energy expenditure of wood was highest -- 40.37 MJ/meal or 7.35 MJ/person per meal.

These values for electricity are point-of-use values. In some of the later parts of this report, we account for the energy expenditure of producing and distributing it. At the time of the survey, a standard 13-kg cylinder of gas cost FJD 13.35 and kerosene averaged 42 t/L.

The relative efficiencies of the different fuels were influenced by family eating habits, which in turn were influenced by the cultural background of each household. Fijians, for instance, did more baking than other groups and consequently were more likely to have ovens. Figure 11 shows what percentages of total consumption of electricity, LPG, kerosene and wood were accounted for by each of the three socio-cultural groups defined previously. Indo-Fijians and Fijians were the main users of kerosene and wood. Indo-Fijians were the main users in all categories of fuel but predominated especially in the use of LPG.

The choice of cooking fuels was, as we may expect, strongly influenced by income. Use of the cheaper fuels -- wood and kerosene -- declined and that of the more expensive fuels -- LPG and electricity -- increased with increasing income (Fig. 12). Correlations between income and quantities of fuels were high -- 0.79 for wood, 0.90 for kerosene, 0.95 for LPG, and 0.87 for electricity. Use of LPG began only with income above FJD 1500 and use of electricity for cooking began only with income above FJD 2000.

Surveyors asked respondents whether, when they were cooking, they would prefer wood-burning stoves or charcoal cookers to open fires or kerosene cookers. Of all sample households, 63% replied they would be interested in buying wood-burning stoves, 16% said they would buy such

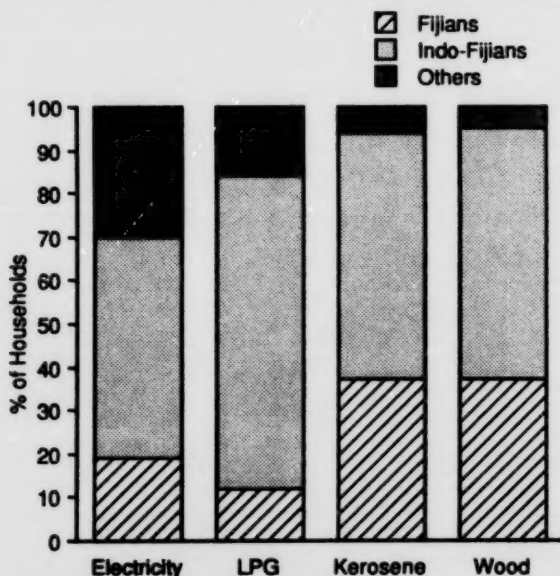


Fig. 11. Percentages of total consumption of cooking fuels used by different cultural groups.

a stove if wood were available, 19% were not interested, and 2% did not respond.

Cooking with charcoal is not traditional or widely practiced in Fiji. When asked whether they would buy a charcoal cooker, 38% of surveyed households said no, 46% said yes, and 13% said yes if they could get charcoal easily.

When asked to compare current use of wood for cooking with that of 2 years earlier, 50% of householders said it had not changed substantially and 22% said it had decreased, either because wood was less available (11%) or because they were using more kerosene (6%) or for other reasons (5%). Of those surveyed, 20% said they were using more wood, and 20% of these cited the rising price of kerosene. These responses indicated that many households were finding kerosene expensive and were switching to wood where it was available. However, wood is, in some areas, becoming scarce. Thus, there is considerable potential for charcoal as a cheaper alternative to kerosene, a possibility that is discussed later in this report.

To summarize the use of energy for cooking: in the nonelectrified households, the average energy used annually per person was 4717 MJ, of which kerosene accounted for 29% and wood 71% (use of LPG was negligible). In the electrified households, annual consumption of energy for cooking averaged 2797 MJ/person, of which kerosene

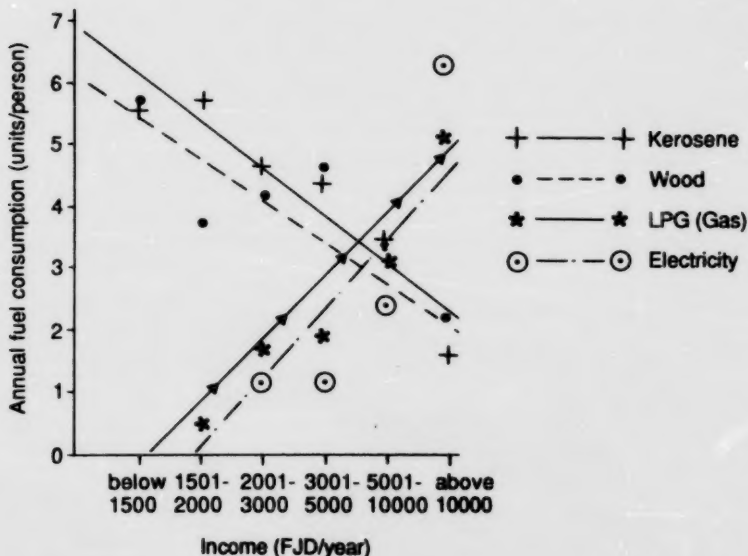


Fig. 12. Variation with income of consumption per person of different cooking fuels. In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar). (Note: 1 unit on the Y-axis scale differs for the different fuels: kerosene, 10 L; wood, 20 kg; LPG, 2 kg; electricity, 10 kWh.)

accounted for 50%, wood 29%, gas 16%, and electricity 5%. We have established that 28% of households in our study area were nonelectrified and that electrified households had an average of 5.49 members as against 5.84 members for nonelectrified households. Assuming that diesel generators are 30% efficient, we can calculate that the total average per capita annual consumption of energy in Suva urban for cooking is 3549 MJ, of which 40% comes from kerosene, 42% from wood, 9% from LPG, and 9% through electricity.

### Lighting fuels

All households that had electricity used it for lighting; in the other households, kerosene and benzine (white, unleaded petroleum, known in some parts of the world as naptha) were common lighting fuels with kerosene being the most commonly used in all households surveyed (Fig. 13). Electricity was used not only for interior lighting but, increasingly, for exterior security lighting. Incandescent lighting is slightly more expensive than fluorescent lighting but is, nevertheless, more commonly used (Table 4). On average, security lights accounted for 10% of the total monthly lighting bill of FJD 3.46.

In the nonelectrified households, 94% had at least one kerosene lamp and averaged 2.3 kerosene lamps, each lit for an average of 70 hours/week. Hourly fuel consumption averaged 9.9 mL at a cost of 0.4 ¢, giving a weekly household consumption of 1.6 L at a cost (45 ¢/L) of 72 ¢. Types of kerosene lamps in use included table lamps (in 50% of nonelectrified households), hurricane lamps (in 57% of nonelectrified households), and pressure lamps (in 4% of nonelectrified households).

Benzine lamps were present in 64% of nonelectrified households and averaged one such lamp per nonelectrified household, each lit for 27 hours/week and consuming 69.4 mL/hour at a cost of 3.2 ¢; this gives a weekly household consumption of 1.84 L at a cost of 86 ¢. A

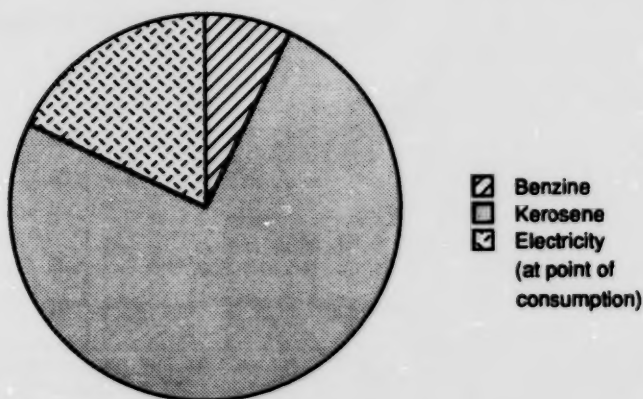


Fig. 13. Use of energy per person for household lighting.

Table 4. Domestic electric lighting.

|                    | Users<br>(%) | Users only              |                                      | Overall                 |                         |
|--------------------|--------------|-------------------------|--------------------------------------|-------------------------|-------------------------|
|                    |              | Mean<br>(kWh/<br>month) | Mean<br>(FJD/<br>month) <sup>a</sup> | Mean<br>(kWh/<br>month) | Mean<br>(FJD/<br>month) |
| Home               |              |                         |                                      |                         |                         |
| Fluorescent tubes  | 77.35        | 10.56                   | 1.59                                 | 8.18                    | 1.12                    |
| Incandescent bulbs | 86.55        | 14.44                   | 2.17                                 | 12.50                   | 1.87                    |
| Security           |              |                         |                                      |                         |                         |
| Fluorescent tubes  | 3.26         | 12.67                   | 1.90                                 | 0.41                    | 0.06                    |
| Incandescent bulbs | 12.96        | 15.21                   | 2.28                                 | 1.97                    | 0.30                    |
| Total              | 100.00       | 23.05                   | 3.46                                 | 23.06                   | 3.46                    |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

more accurate survey taken in rural Fiji in 1977 (Siwatibau 1981) showed that benzine consumption averaged 49 mL/hour; kerosene lamps varied in mean consumption from 12 to 48 mL/hour.

The survey established that 15% of nonelectrified households had battery electric lighting and that a set of batteries lasted on average 3.8 weeks. Also, among electrified households, 7% regularly used kerosene lamps for an average of 55 hours/week; 5% had benzine lamps but less than 1% used them regularly for an average of 7.6 hours/week.

Lights for night fishing were used by 5% of electrified households and 17% of nonelectrified households. Of those who used lights for fishing, 78% used benzine pressure lamps and 12% used battery-operated flashlights.

Of the three main types of lighting fuel used in the Suva urban area, kerosene is the cheapest. A fluorescent tube using 50 W/hour at 15 ¢/kWh costs 0.75 ¢/hour and therefore is less expensive than benzine lighting.

### Appliances

We defined an "electric appliance" as anything that used electricity other than lighting.

As people become urbanized and fresh food becomes less available to them, domestic refrigeration becomes more essential. Thus refrigerators were among the appliances most likely to be found in a household (Table 5) and were major consumers of domestic energy. With an average wattage of 158, they consumed an estimated 65.5 kWh/month.

Our surveyors visited six major retailers and examined the refrigerators in stock. Most were between 0.2 m<sup>3</sup> and 0.9 m<sup>3</sup> in

Table 5. Summary of electric appliance survey.<sup>a</sup>

| Appliance                  | % of households | Appliances per household | % owner users | Wattage | Hours of use/week | User household |                        | Suva urban household |           |
|----------------------------|-----------------|--------------------------|---------------|---------|-------------------|----------------|------------------------|----------------------|-----------|
|                            |                 |                          |               |         |                   | kWh/month      | FJD/month <sup>b</sup> | kWh/month            | FJD/month |
| Laundry irons              | 97.1            | 0.99                     | 99.5          | 250     | 3.2               | 3.5            | 0.52                   | 3.4                  | 0.50      |
| Refrigerators <sup>c</sup> | 89.9            | 0.91                     | 100.0         | 158     | 95.8              | 65.6           | 9.84                   | 59.0                 | 8.85      |
| Radios/cassette players    | 61.9            | 0.64                     | 97.7          | 8       | 40.2              | 1.4            | 0.21                   | 0.8                  | 0.13      |
| Stereo                     | 49.6            | 0.51                     | 95.3          | 50      | 23.9              | 5.2            | 0.78                   | 2.5                  | 0.37      |
| Fan                        | 46.1            | 0.54                     | 80.3          | 46      | 6.9               | 1.4            | 0.21                   | 0.5                  | 0.08      |
| Jug/kettle                 | 25.7            | 0.26                     | 76.8          | 1530    | 2.7               | 17.3           | 2.60                   | 3.4                  | 0.51      |
| Sewing machine             | 24.3            | 0.25                     | 73.0          | 60      | 2.6               | 0.7            | 0.11                   | 0.1                  | 0.02      |
| Television                 | 23.2            | 0.24                     | 99.2          | 150     | 12.2              | 8.0            | 1.19                   | 1.8                  | 0.27      |
| Stored-water heater        | 22.5            | 0.22                     | 23.6          | 987     | 91.6              | 2191.0         | 32.91                  | 11.6                 | 1.75      |
| Solar booster              | 2.8             |                          | 100.0         | 4300    | 168.0             | 96.3           | 14.45                  | 2.7                  | 0.40      |
| Stove                      | 21.3            | 0.21                     | 73.5          | 740     | 4.3               | 94.0           | 14.05                  | 14.7                 | 2.21      |
| Washing machine            | 19.9            | 0.20                     | 95.6          | 600     | 1.2               | 13.8           | 2.08                   | 2.6                  | 0.39      |
| Frypan                     | 14.6            | 0.15                     | 73.0          | 820     | 2.8               | 3.1            | 0.47                   | 0.3                  | 0.05      |
| Rice cooker                | 11.9            | 0.12                     | 81.7          | 1200    | 2.0               | 10.0           | 1.50                   | 1.0                  | 0.15      |
| Immersion heater           | 8.9             | 0.09                     | 72.2          | 3000    | 5.2               | 10.4           | 1.57                   | 0.7                  | 0.10      |
| Instant water heater       | 7.8             | 0.08                     | 90.0          | 160     | 168.0             | 67.3           | 10.10                  | 4.7                  | 0.71      |
| Freezer <sup>d</sup>       | 6.2             | 0.07                     | 92.5          | 710     | 1.3               | 117.0          | 17.54                  | 6.7                  | 1.01      |
| Food blender               | 4.4             | 0.04                     | 68.2          | 1650    | 11.7              | 4.0            | 0.60                   | 0.1                  | 0.02      |
| Air conditioner            | 3.7             | 0.04                     | 55.6          | 637     | 3.3               | 84.0           | 12.60                  | 1.7                  | 0.26      |
| Other                      | 19.1            | 0.28                     | 83.6          | 637     |                   | 9.1            | 1.37                   | 1.5                  | 0.22      |

<sup>a</sup> Users were those who had their appliances turned on more than 30 min/week (except for stored-water heaters, who were those who had them turned on more than 30 min/day), and electric stove users, defined as those who cooked at least one meal/day on the stove.

<sup>b</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

<sup>c</sup> Only refrigerators in use were recorded on the questionnaire; 88.2% of refrigerator owners had one refrigerator and 1.3% had two refrigerators.

<sup>d</sup> Wattages for frypans, instant water heaters, and freezers are estimated means.

external volume, the most popular size being  $0.5 \text{ m}^3$ , and currents were 0.7 A to 2.4 A. The electric supply in Suva is 240 V. New Zealand was the major supplier, with Japan a distant second; the New Zealand products in general had less adequate insulation than those from Japan and the USA. The rated internal volumes were within 5% of actual measured capacity. Most refrigerators automatically defrosted.

In a survey of household refrigerators, we found that average rated wattage generally increased linearly with size, from a mean of 129 W for refrigerators of  $0.1 \text{ m}^3$  to a mean of 211 W for those of  $0.6 \text{ m}^3$ . Monthly electricity consumption also increased with size, from 39 kWh for the smallest to 87 kWh for the  $0.6 \text{ m}^3$  size and 131 kWh for the  $0.8 \text{ m}^3$  size. However, although the consumption-size relationship was more-or-less linear, the medium refrigerators were somewhat more efficient in consumption per cubic metre. Newer refrigerators appeared more energy-efficient than older ones, although those over 15 years old also had low consumption figures; however, the sample was too small to yield firm conclusions.

In addition to the electric refrigerators, 4% of nonelectrified householders owned refrigerators run on kerosene. Such appliances were of  $0.17\text{--}0.76 \text{ m}^3$  capacity, with an average of  $0.44 \text{ m}^3$ , and consumed 2-9 L of fuel/week, with an average of 5.1.

Averaged over the entire population of the Suva urban area, kerosene refrigeration consumed 19.6 MJ/person and electric refrigeration consumed 981.3 MJ/person.

An important energy-consuming domestic activity in Suva is the ironing of clothes; 97% of electrified households used electric irons, averaging 3.5 kWh/month, and 65% of nonelectrified households used benzine irons, averaging 1.2 L/week. For the entire study area, benzine irons accounted for 1.9 L/year (65.4 MJ/year) per person and electric irons, 5.3 kWh/year (57.2 MJ/year at generation, assuming 30% efficiency) per person.

Piped hot-water systems were a luxury available to 36% of the electrified population. Of the electrified households, 27% had stored-water systems and 9.4% had instant-heater piped-water systems. Electricity was the most popular means of heating water (Table 6), but gas, wood, and solar heaters were also used with the distribution of these systems being associated with level of income. The degree to which the systems were used also increased with income: most consumers were conscious of the cost of hot water and turned on their heaters only as required. Thus, the FJD 2001-3000/year group switched on their systems for only an average 1.5 hours/day, whereas the average for the >FJD 10,000 group was 5.5 hours. The overall mean was 3.9 hours. Our survey showed that electric heaters, if switched on for at least 3 hours, have an average duty cycle of 56%. At shorter periods, the element is on for a greater proportion of the time as it heats the water from the ambient temperature to the thermostat setting.

Overall, 27% of the electrified households had storage water heaters, of which 10% were solar heaters. These were usually of the flat-plate type, roof-mounted with adjacent low-pressure tanks. Gas consumption for water heating was not thought sufficiently significant to disaggregate from the cooking statistics.

Table 6. Percentage of households by income group with stored hot water and instant heater piped systems.

| Cash incomes<br>(FJD/year) <sup>a</sup> | Stored hot water |          |      |       | Instant heaters |          |
|-----------------------------------------|------------------|----------|------|-------|-----------------|----------|
|                                         | Gas              | Electric | Wood | Solar | Gas             | Electric |
| <1500 <sup>b</sup>                      | 0.0              | 3.2      | 0.0  | 0.0   | 0.0             | 0.0      |
| 1501-2000                               | 0.0              | 0.0      | 0.0  | 0.0   | 0.0             | 8.6      |
| 2001-3000                               | 0.0              | 5.4      | 0.0  | 0.9   | 1.8             | 2.7      |
| 3001-5000                               | 0.4              | 9.1      | 0.0  | 0.0   | 0.0             | 7.0      |
| 5001-10000                              | 2.8              | 26.8     | 0.0  | 3.4   | 2.5             | 8.3      |
| >10000                                  | 2.3              | 41.9     | 0.4  | 6.0   | 2.3             | 10.9     |
| Total                                   | 1.6              | 22.5     | 0.1  | 2.8   | 1.6             | 7.8      |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

<sup>b</sup> All respondents in the <FJD 1500/year group indicated their systems were not in use.

Electric water heaters were of 1-2 kW capacity. Our surveys of appliances and electric bills showed electric water heaters consumed an average of 19 kWh/month. For all urban Suva, therefore, yearly consumption averaged 164 kWh/household or 28.9 kWh/person. Thus (again using 30% generation efficiency), total energy consumption per person in the study area for electric water heating would be 313 MJ/year.

We estimated that those who used electric stored-water heaters spent an average of FJD 32.91/month on them, whereas those with solar water heaters and boosters spent an average FJD 14.45. The latter had piped hot water available 24 hours/day, whereas the former had it only when they needed it, as the device was switched on only an average of 3.9 hours/day. Should the user of an electric water heater leave it on 24 hours/day, the monthly cost would be FJD 60.36.

Thus, even when supplemented by an electric booster, solar water heating provides savings for those using only electric water heating. A six-person household can have a 273-L solar water system installed for FJD 935. If the electric heater is then used only as a booster, the family can have 24-hour hot water and still save FJD 18.46/month on electricity, giving a pay-back period for the solar heater of 51 months.

A variety of appliances used electricity, notably home freezers, which used an average of 117 kWh/month; these, however, were found in only 6% of surveyed households. Air-conditioners were major consumers of energy at 84 kWh/month. Their overall impact was small, however, because they were to be found in only 4% of surveyed households. Figure 14 summarizes the percentages of electricity consumed in each end use domestically. The entire population within the study area consumed 238 kWh/year per person, accounting for 2827 MJ/year at the point of generation.

There is a marked association between cultural groups and appliance use and also between income groups and appliance use. Fijians have the lowest proportion of households with appliances (Table 7) and, not unexpectedly, appliance ownership rises with income.

### Transport

Transport accounted for a substantial use of energy in Suva urban. Only 22% of workers in the study area walked to work regularly, taking an average of 13.8 minutes to do so; 52% of children walked to school, taking an average 12.6 minutes.

About 71 children from each 100 households travelled to school by bus, averaging 4.9 km. Some 78% of Suva households used bus services regularly at a cost of FJD 4.47 weekly. Those who used taxis fairly regularly (29%) spent an average of FJD 3.63 on them. Bringing home a week's groceries was the most common use of taxis.

Among the car-owning population, Japanese imports were overwhelmingly the most popular -- in 1981, according to the Bureau of Statistics, 99% of imported cars came from Japan. In the surveyed population, 70% of cars were of 1.1-2.5 L capacity, 6% were smaller and 16% larger. Survey teams were unable to establish the size of the remainder. Bicycles appeared to be gaining in popularity.

Among electrified households, 45% owned cars, 3% owned motorcycles, 6% owned bicycles, 4% owned taxis, and 8% owned other types of vehicles. Equivalent values for nonelectrified households were 1.7, 0.3, 0.3, 0.0, and 0.3%. Equivalent values for all households in the study area were 33, 2, 4, 3, and 6%. Among the better-off households, only 20% shared vehicles, whereas 75% of the less-well-off regularly did so. The survey established that of the vehicles that were shared:

- \* 16% shared for >50% of trips;
- \* 11% shared for 20-50% of trips;

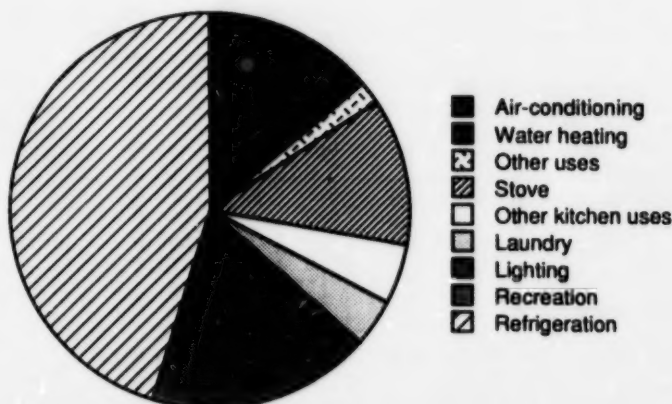


Fig. 14. Uses of electricity in an electrified house.

- 18% shared for 10-20% of trips;
- 22% shared for <10% of trips; and
- 33% were shared for an unknown number of trips.

We estimated that 29% of bus fares in 1981 were for diesel fuel. At the wholesale price of 32.59 t/L, this puts the estimated consumption at 4.0 L/household per week. Applying the 29% figure to taxi fares, we find that fuel cost would be FJD 1.05 of the average weekly taxi cost per household of FJD 3.63. Most taxis were operated on gasoline, the retail price of which was 47.6 t/L. This puts the average weekly consumption of gasoline for taxis at 2.2 L/household.

The survey obtained estimates of fuel consumption of private vehicles during interviews. Those who owned motor vehicles averaged fuel costs per household of FJD 10.80 weekly. Assuming this is mostly gasoline, this gives us a value of 22.7 L/household per week.

Buses were used by 78% of all households, taxis by 29%, and private vehicles by 34%. It is thus possible to calculate that, for the whole study area, annual use per person of bus diesel fuel was 28.8 L (1106 MJ), of taxi gasoline 6.0 L (205 MJ), and of private vehicle gasoline 72.5 L (2495 MJ). Total energy used for transport in Suva urban was 3806 MJ/year. Table 8 shows weekly expenditures by income group on public transport.

It is clear that a person who used a private motor vehicle was consuming at least twice as much transport energy as one who used buses. Ownership of a private car rose with income, as did ownership of a second car (Table 9). The association of income with fuel consumption for private vehicles was less clear, however, probably

Table 7. Distribution of electrical appliances by income and cultural group.

|                                | Households<br>with<br>videos<br>(%) | Households<br>with storage<br>water heater<br>(%) | Households<br>with working<br>refrigerator<br>(%) | Other<br>appliances<br>(Average<br>number per<br>household) |
|--------------------------------|-------------------------------------|---------------------------------------------------|---------------------------------------------------|-------------------------------------------------------------|
| Income (FJD/year) <sup>a</sup> |                                     |                                                   |                                                   |                                                             |
| <1500                          | 3.0                                 | 0.0                                               | 54.8                                              | 2.16                                                        |
| 1501-2000                      | 0.0                                 | 0.0                                               | 57.1                                              | 2.63                                                        |
| 2001-3000                      | 4.5                                 | 6.3                                               | 70.5                                              | 2.67                                                        |
| 3001-5000                      | 11.9                                | 9.5                                               | 84.8                                              | 3.33                                                        |
| 5001-10000                     | 28.0                                | 33.0                                              | 100.0                                             | 4.64                                                        |
| >10000                         | 42.3                                | 50.6                                              | 100.0                                             | 6.47                                                        |
| Cultural group                 |                                     |                                                   |                                                   |                                                             |
| Fijian                         | 3.8                                 | 6.9                                               | 77.0                                              | 2.8                                                         |
| Indo-Fijian                    | 32.2                                | 31.5                                              | 94.0                                              | 4.9                                                         |
| Other                          | 28.5                                | 51.2                                              | 99.0                                              | 6.3                                                         |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

because of ownership of taxis and the preponderant use of cars for traveling to work; these factors rendered fuel-use nonincome-elastic. For the whole population, however, income group is correlated (0.97) with transport fuel consumption (Fig. 15), because of the association between income and car ownership.

Mobility patterns also show interesting associations with cultural groups. Fijians had a greater tendency to use buses and taxis, whereas Indo-Fijians and "Others" were more likely to own cars (Table 10). Fijians who did have cars were most likely of the three cultural groups to share them, whereas Indo-Fijians were least likely. All Fijians who owned cars drove them to work, whereas 3% of Indo-Fijians and 8% of "Others" did not do so.

To sum up, high-income households were more likely to own cars but also tended to use bus and taxi services more than low-income

Table 8. Expenditures on public transport by income group.

| Income<br>(FJD/year) | Bus (FJD/week) <sup>a</sup> |             | Taxi (FJD/week) |             |
|----------------------|-----------------------------|-------------|-----------------|-------------|
|                      | Nonelectrified              | Electrified | Nonelectrified  | Electrified |
| <1500                | 2.35                        | 2.94        | 1.03            | 1.52        |
| 1501-2000            | 3.91                        | 3.66        | 0.44            | 0.71        |
| 2001-3000            | 3.99                        | 4.00        | 0.84            | 0.71        |
| 3001-5000            | 4.31                        | 4.02        | 0.89            | 1.12        |
| 5001-10000           | 4.57                        | 3.38        | 2.07            | 1.20        |
| >10000               | - <sup>b</sup>              | 2.29        | - <sup>b</sup>  | 0.96        |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

<sup>b</sup> Unknown.

Table 9. Households owning cars by income group (%).

| Income<br>(FJD/year) <sup>a</sup> | 1st car        |      | 2nd car |      | Motorcycle |     | Taxi |     | Other |     |
|-----------------------------------|----------------|------|---------|------|------------|-----|------|-----|-------|-----|
|                                   | N <sup>b</sup> | E    | N       | E    | N          | E   | N    | E   | N     | E   |
| <1500                             | 0.0            | 0.0  | 0.0     | 0.0  | 0.0        | 0.0 | 0.0  | 0.0 | 0.0   | 0.0 |
| 1501-2000                         | 0.0            | 5.7  | 0.0     | 0.0  | 0.0        | 0.0 | 0.0  | 0.0 | 0.0   | 0.0 |
| 2001-3000                         | 1.7            | 17.9 | 0.0     | 0.0  | 0.0        | 0.0 | 0.0  | 4.5 | 0.0   | 0.0 |
| 3001-5000                         | 1.5            | 21.8 | 0.0     | 1.2  | 0.0        | 0.0 | 0.0  | 3.4 | 0.0   | 2.9 |
| 5001-10000                        | 6.6            | 43.7 | 0.0     | 4.6  | 0.0        | 2.8 | 0.0  | 3.1 | 0.0   | 5.6 |
| >10000                            | 0.0            | 66.8 | 0.0     | 12.1 | 0.0        | 3.4 | 0.0  | 3.8 | 0.0   | 4.5 |
| Total                             | 1.7            | 39.0 | 0.0     | 4.9  | 0.0        | 1.8 | 0.0  | 3.3 | 0.0   | 4.5 |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

<sup>b</sup> Nonelectrified (N) and electrified (E).

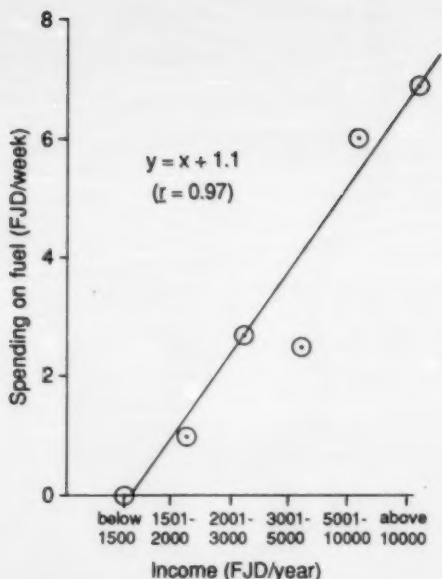


Fig. 15. Variation with income of consumption of fuel for private cars. In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

households and were thus more mobile. Energy consumption per person for transport was much higher for those with cars than for those without. Of all energy other than human energy used for personal transportation in the study area, 70% was used in private cars, 25% in buses, and 5% in taxis.

#### Fuel supplies

Those who used wood regularly for cooking usually got it free from their own compounds (18%) or nearby scrubland (58%). Others (6%) got it free from sawmills or forests outside Suva, paying only for transport, an average of FJD 8.53/year. Those who bought wood paid an average of FJD 15.76/year at FJD 8.60/t. Such wood was usually offcuts from sawmills. We surveyed small grocery shops and found only one that retailed wood, charging 50 ¢ for a bundle of about 8.5 kg.

No data are available on the sustainability of fuelwood supplies. However, of those who decreased their use of wood, 53% asserted it was becoming less available. In contrast, an equal number of householders had increased their use of wood, their reason being, in 61% of cases, the increasing price of such commercial alternatives as kerosene and gas.

Our analysis showed that types of wood in use came from processed wood (box timber, offcuts, and sawmill wastes), mangrove (dabi, diridamu, dogo, gagali, ivi, sagale, tiri, and vasa), home compounds

Table 10. Means of transport used by cultural groups.

|                                                                  | Fijian | Indo-Fijian | Other |
|------------------------------------------------------------------|--------|-------------|-------|
| Households where at least one member walked to work each day (%) | 15     | 15          | 15    |
| Students walking to school (number/100 households)               | 61     | 54          | 33    |
| Students traveling by bus to school (number/100 households)      | 110    | 49          | 46    |
| Mean distance traveled to school (km)                            | 5.1    | 4.7         | 4.8   |
| Mean household bus fares (FJD/week) <sup>a</sup>                 | 4.82   | 2.86        | 1.95  |
| Mean household taxi fares (FJD/week)                             | 1.83   | 0.59        | 1.51  |
| Mean household gasoline cost (FJD/week)                          | 1.60   | 6.30        | 6.20  |
| Private cars (number/100 households)                             | 14     | 55          | 64    |
| Motorcycles (number/100 households)                              | 2      | 2           | 7     |
| Bicycles (number/100 households)                                 | 2      | 6           | 14    |
| Taxis owned (number/100 households)                              | 3.0    | 4.4         | 3.0   |
| Vehicle owners who shared vehicles with neighbours (%)           | 45     | 16          | 23    |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

(breadfruit, cassava, coconut, mango, and soursop), scrubland (guava, niuniu, and vaivai), primary forest (bauvudi, buabua, dakua, damanu, kaudamu, kauvula, laubu, tavotavo, vulavula, and yasiyasi), plantation forest (mahogany and pine) and secondary forest (caukuro, raintree, sa, sea, vacea, and vala). Average moisture content was 35.5% (on an oven-dry basis).

Kerosene is easily transported and stored and is readily available from small neighbourhood shops, where 95% of users bought some or all of their supplies. However, 15% patronized oil suppliers or service stations and 2% got theirs free from the government. The most popular container was the 1-gal (4.55-L) size, used by 65% of respondents, followed by the 740-mL bottle, the 4-gal (18.18-L) drum, and the 0.5-gal (2.27-L) container.

Most grocery shops surveyed sold kerosene, averaging 324 L/week with a range of sales of 20-2000 L. The mean price was 42 ¢/L; prices did not vary greatly between outlets, except that our nonelectrified households were located in squatter areas on the outskirts of the city

Table 11. Overall quantity and cost of domestic fuels used in urban Suva.

| Energy source <sup>a</sup> | Quantity                | Aggregate cost to all consumers (FJD 000) <sup>b</sup> | Energy value (GJ x 10 <sup>4</sup> ) |
|----------------------------|-------------------------|--------------------------------------------------------|--------------------------------------|
| Gasoline (L)               | 12.60 x 10 <sup>6</sup> | 5998 (35) <sup>c</sup>                                 | 43.34 (33)                           |
| Kerosene (L)               | 6.90 x 10 <sup>6</sup>  | 2925 (17)                                              | 25.32 (19)                           |
| Wood (t)                   | 1.27 x 10 <sup>4</sup>  | 13 (<1)                                                | 24.90 (19)                           |
| Diesel (L)                 | 4.60 x 10 <sup>6</sup>  | 1495 (9)                                               | 17.66 (13)                           |
| Electricity (MWh)          | 3.59 x 10 <sup>4</sup>  | 5390 (31)                                              | 12.93 (10)                           |
| LPG (t)                    | 1.03 x 10 <sup>3</sup>  | 1055 (6)                                               | 5.14 (4)                             |
| Benzine (L)                | 0.70 x 10 <sup>6</sup>  | 280 (2)                                                | 2.41 (2)                             |
| Total                      |                         | 17155                                                  | 131.7                                |

<sup>a</sup> Wood is calculated at FJD 8.60/t fresh weight at 35.8% moisture content (survey results indicate only 9% of households paid for their wood); gasoline is calculated at 47.6 t/L retail; and diesel (automotive fuel) is calculated at 32.5 t/L wholesale.

<sup>b</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

<sup>c</sup> Values in parentheses are percentages of total.

and were served by very small shops that in many cases charged somewhat more for their goods than did large retail outlets in the city proper. Thus, nonelectrified households averaged about 45 t/L.

LPG is distributed in Fiji by two companies, both of which operate in Suva. They distribute the product directly or through agents in standard 13-kg containers. At the time of the survey, a 13-kg container cost FJD 13.35.

Benzine is less widely used than kerosene. Only 25% of the suburban grocery shops surveyed sold it; average sales, at 40 t/L, were 94 L weekly, ranging from 1-220 L. Again, nonelectrified householders appeared to pay more, an average of 47 t.

The total quantities and cost of energy in the Suva urban area are set out in Table 11. Table 12 shows the per-person annual consumption and use of each source of energy.

### Discussion

Conservation and substitution are, for most countries in the developing world, the major areas on which energy policymakers focus. Our survey shows a potential in Suva for both types of action. Some measures can have an impact on the national economy; others will primarily benefit consumers. The survey showed four factors that must be taken into account when forecasting future trends in energy demand: population growth; changes in incomes; cultural practices; and the purpose of using energy.

Table 12. End uses of household energy sources (MJ/year per person).

| Energy source <sup>a</sup> | Cooking        | Lighting     | Refrig-<br>eration | Piped<br>water | Transport      | Other        | Total                    |
|----------------------------|----------------|--------------|--------------------|----------------|----------------|--------------|--------------------------|
| Gasoline                   |                |              |                    |                | 2700.1         | na           | 2700.1 (27) <sup>c</sup> |
| Electricity                | 317.5          | 391.0        | 1101.2             | 312.6          |                | 405.0        | 2527.3 (25)              |
| Kerosene                   | 1402.1         | 172.5        | 19.6               |                |                |              | 1594.2 (16)              |
| Wood                       | 1509.8         |              |                    |                |                | 25.7         | 1535.5 (16)              |
| Diesel                     |                |              |                    |                | 1105.5         |              | 1105.5 (11)              |
| LPG                        | 319.3          |              |                    | - <sup>b</sup> |                |              | 319.3 (3)                |
| Benzine                    |                | 106.6        |                    |                |                | 65.4         | 172.0 (2)                |
| Total                      | 3548.7<br>(36) | 670.1<br>(7) | 1120.8<br>(11)     | 312.6<br>(3)   | 3805.6<br>(38) | 496.1<br>(5) | 9953.9                   |

<sup>a</sup> Electricity is at generation, assuming 30% efficiency; diesel is automotive only (an unknown quantity is used for mowing); other uses for wood include laundry and hot water, and for benzine include ironing; and refrigeration use includes home freezers.

<sup>b</sup> Negligible amount.

<sup>c</sup> Values in parentheses are percentages of totals.

## Transport

Petroleum for household transport is the single most important energy use, accounting for 35% of the whole (Table 11). In 1982, Suva's urban dwellers used over 12 million L of gasoline for private transport at a cost to themselves of nearly FJD 6 million. Table 12 shows that gasoline for this purpose accounted for 2700 MJ/year per person -- the equivalent value for Lautoka-Nadi was 2439 (Lloyd et al. 1982) and for Hong Kong 1923 (Newcombe et al. 1978). Total per-person energy consumption values (in MJ/year) for all forms of transportation were: Suva, 3805; Lautoka-Nadi, 2730; and Hong Kong, 2551.

Hong Kong has a public rail-transport system; nevertheless, the figures show there is a clear potential in Fiji for saving energy on transport. Fuel savings would result through the gradual replacement of the present fleet of vehicles with more efficient ones. In New York City, replacing vehicles by more fuel-efficient ones is thought to have produced savings of 50% in automobile fuels and 20% in truck diesel fuels. The potential in Fiji is there but cannot be readily estimated without information on the performance of present vehicles.

Even without replacement of vehicles, fuel savings would be available through increased car sharing, driver education, and better maintenance, all of which need to be encouraged in Suva.

One would expect that encouraging the use of public transport would also save fuel; however, Suva's householders already make considerable use of buses. Our survey shows that the energy expended in Suva on bus transport amounts to 41% of that used on cars and taxis. Equivalent values are 12% for Lautoka-Nadi and 33% for Hong Kong.

## Cooking

The other high-energy-consuming household activity, cooking, mostly uses kerosene and wood. Our tests indicated these heat utilization figures: multiwick kerosene burner, 49.6%; Primus pressure stove, 49.4%; electric stove element, 44.3%; and charcoal stove, 40.7%. It seems unlikely that the kerosene stove's efficiency can be greatly improved without rendering it too expensive a purchase. The only alternative for savings appears to be substitution of kerosene by a cheaper, possibly local, fuel.

Using wood in open fires, a common practice in Suva, is wasteful. The Fiji Government has a program to introduce efficient woodburning stoves, although whether this will reduce wood consumption is yet to be seen. Certainly it is well understood that these stoves will improve health and social conditions in cooking.

## Refrigeration

Conservation in the use of electricity, though not of great national significance, would benefit consumers. A major step would be to identify and promote more efficient refrigerators and freezers. A survey reported by Harding (1982) indicated a 50% reduction in the consumption of energy as a result of using Japanese models. The most efficient model was the 425-L Toshiba GR-411, said to consume 550 kWh/year -- far below the 1696 kWh/year measured in equivalent refrigerators in our Suva survey. According to retailers, the most

popular refrigerator on the market is 300 L (external volume 5 m<sup>3</sup>), a size that averaged 887 kWh/year and was the third most efficient size.

In our survey, the most efficient refrigerators consumed 139 kWh/m<sup>3</sup> per month, whereas the Toshiba GR-411 consumes 115 kWh/m<sup>3</sup> per month. This suggests that introduction of more efficient models could lead to a 17% energy saving. However, these efficient refrigerators cost much more than those currently retailed in Fiji.

There is, however, scope for savings through consumer education in the use of refrigerators and freezers. Our survey indicated consumers in general were unaware of the need to keep the condenser well aerated to conserve energy. Of the refrigerators surveyed, 89% were less than 20 cm from the wall, so there was little air movement around the condensers. Only 9% were 21-30 cm from the wall and 2% were more than 30 cm from the wall.

Most consumers recognized that a warmer setting used less electricity: 52% of thermostats were set at warm, 38% at cold, and 10% at coldest. Equally, most consumers kept their refrigerators in good condition; 74% had ice less than 6 mm thick.

Thus it seems clear that consumers will respond well to education designed to help them save energy. What savings are likely to be made can be assessed only through experience.

### Lighting

Of the total average lighting consumption of 23.0 kWh/month for an electrified household, 12.5 was for incandescent bulbs and 8.2 kWh was for fluorescent tubes. Incandescent bulbs use more energy than fluorescent tubes to produce the same quantity of illumination, and they last only 1000 hours against the 5000 hours of the tubes. (Philips "PL" and "SL" lamps are also available; these have the advantages of fluorescent tubes but retain the qualities of incandescent lighting.)

The survey found that the average electrified home had two fluorescent lamps lit concurrently 3.7 hours/day and three incandescent bulbs 3.3 hours/day. The most popular bulb sizes were 60 and 75 W and the most popular fluorescent tubes were 20 and 40 W. We calculated that if a 60-W bulb is replaced by a 20-W tube, the payback period would be 1.9 years. If a 75-W bulb is replaced by a 40-W tube the payback period would be 2.1 years. There would be a payback period of 1.3 years if a 75-W bulb is replaced by an 18-W "SL" lamp.

Replacing all incandescent bulbs with fluorescent tubes would produce an average saving of 5.7 kWh/month per household: the saving would be 10.6 kWh using "SL" lamps.

### Incomes and cultural practices

The two most important household energy-using activities, cooking and transport, were affected by incomes in different ways. Suva's urban households used four main cooking fuels, the choice of which was clearly associated with income. The survey showed that, with increases in cash incomes, the use of wood and kerosene lessened and that of LPG and electricity increased. As kerosene and LPG are both

imported and as LPG appears to be a more efficient fuel than kerosene, the trend toward LPG should be allowed to continue.

Electricity as a cooking fuel is likely to remain too expensive for most consumers for many years, even though it is now produced locally (in Viti Levu) by hydrogeneration.

For those with the lowest incomes, for whom even kerosene is too expensive and free wood is scarce, the introduction of new, cheap fuels, such as charcoal, needs to be considered. There is also the possibility of replacing kerosene with another liquid fuel, such as cocohol.

There was no clear correlation between incomes and expenditure on buses and taxis, other than between nonelectrified household incomes and bus fares. Similarly, among those who owned vehicles, there was no clear association between fuel consumption and incomes. We interpret this as indicating that mobility of Suva householders is largely associated with basic needs and that any measure to save energy by reducing their mobility will not be effective. Energy conservation may be better achieved by changing the nature of the mobility -- more walking, cycling, use of public transport, and car sharing -- and by improving efficiency with better vehicles, maintenance and driving habits.

Cultural practices also affect some uses of energy, notably cooking. Fijians tend to prefer cookers with ovens for baking, whereas Indo-Fijians do not. Both prefer the single-burner multiwick kerosene cooker, not only because it is cheaper, but because it is suited to the long, slow type of cooking that such dishes as rice and stews need. The less-popular Primus stoves predominate in the households of the "Other" category, probably because this group includes the Chinese, who prefer a very hot, quick flame for their type of cooking. Such factors influence peoples' choice of technology and should, therefore, be taken into account when introducing new ones.

An important determinant affecting energy demand is the purpose for which the energy is expended. For instance, income and electricity demand are closely correlated; rapid increases in household electricity use could doubtless be curbed (should it be necessary) by imposing steep increases in price, especially if the increase were to be graduated. On the other hand, where the energy is used to fulfil a basic need, as for transportation, increases in price may have less effect on consumption.

## THE INDUSTRIAL USE OF ENERGY

The Fiji Bureau of Statistics listed 499 industrial establishments (other than quarrying and mining) in the 1980 Census of Industrial Production. The 1981 directory of the Ministry of Commerce located 36% of the country's industrial establishments in Suva. Discounting the nationally dominant sugar industry (located in urban centres other than Suva), food manufacturing employs more people and consumes more energy than any other type of industry.

All major industries, other than sugar and a large timber mill near Viti Levu, depend on the Fiji Electricity Authority for their electricity. According to the Census of Industrial Production, industry in 1980 spent more on electricity than on any other form of energy -- FJD 4.86 million (41% of total industrial spending on energy), compared with FJD 2.17 million (18%) on heavy fuel oil, FJD 1.74 million (15%) on industrial distillate, FJD 1.47 million (12%) on automotive fuel, FJD 1.46 million (12%) on automotive distillate, FJD 0.2 million (2%) on LPG, and less than FJD 0.1 million on kerosene. Electricity has become increasingly important recently (Fig. 16).

### Methods

According to the Ministry of Commerce directory, there were 178 manufacturing establishments in Suva at the time of our survey. This number was "pruned" to 127 after allowing for establishments that closed or were duplicated in the directory. Initially, we wrote to each of the 127 establishments asking for cooperation in the survey and 76 (60%) of them agreed. Numbers of manufacturers surveyed were: food products, 22 (69% of those in operation); clothing and footwear, 3 (33%); wood products, 7 (100%); paper and printing, 4 (80%); chemicals, 9 (69%); nonmetallic products, 3 (75%); machinery and equipment, 16 (46%); and miscellaneous, 12 (55%). These categories follow the international standard industrial classification code (ISIC).

We mailed to each cooperating establishment a questionnaire asking for information on ownership of the business, time since its establishment, operating times, workforce employed, production costs, volume of production, and waste disposal. The questionnaire asked about the end uses of energy, how much of each energy source was used, and whether the establishment generated electricity and at what cost. One question dealt with use of energy for transport and the last question asked whether steps to reduce energy costs had been taken and if so what.

The questionnaires were followed by telephone calls to the general managers seeking interviews in which to explain the aims and methods of the survey and offering help with the questionnaire.

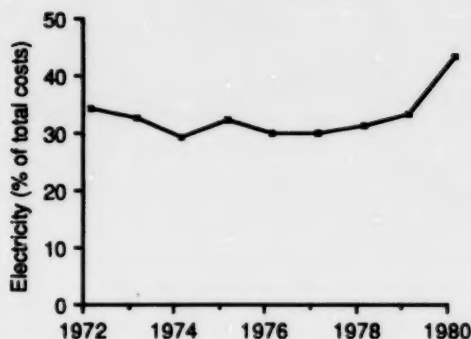


Fig. 16. Electricity as a percentage of total fuel costs for Fiji industries (excluding mining, quarrying, electric generation, gas, and water).

In addition, a survey team consisting of at least one professional project staff member and three student surveyors visited each establishment and filled in data sheets on motors, boilers, air conditioning, lighting, office equipment, and other uses of energy. Methods used to quantify energy use included:

- Measuring with ammeters the current of single-phase motors;
- Reading nameplates of all motors to learn rated power;
- Interviewing managers and employees to assess average loads and hours of use of motors;
- Checking and supplementing survey data from maintenance sheets where possible;
- Using whirling hygrometers to measure temperature and humidity of air-conditioned areas;
- Counting all appliances and noting capacities, hours of use, and fuel consumption; and
- Measuring premises and floor areas and noting those lit and those air conditioned.

The data were transferred to summary sheets, each transfer being checked against possible error.

Survey estimates were checked against company accounts and suppliers' records for accuracy. However, the process was completed only for electricity, as records for other types of fuel were not suitable for our purpose. For instance, suppliers often did not record whether deliveries were of gasoline or diesel fuel, or to which department of a company they were made.

Estimates of electricity consumption, checked against the records

of the FEA, showed differences ranging from less than 1 to 78% with an average difference about 24%. This may be the result of wrong estimates by the surveyors or users; however, monthly bills frequently varied by up to 175% (average variation about 22%), so an average difference between survey results and billings of up to 30% is acceptable. Certain assumptions, in the absence of detailed data, were made for this part of the survey:

- Fluorescent tubes consumed 1.25 times the rated wattage;
- Air conditioners were assumed to run at an average duty cycle of 60%, based on monitoring one large central and three room-size units;
- Small refrigerators were assumed to run at 55% duty cycle and water heaters at 56% duty cycle, based on data gathered in our domestic survey. A detailed survey of two establishments by a visiting consultant led to the assumption that the duty cycles of large freezers and coolroom motors were 60%;
- Based on results from the domestic survey, we assumed a 50% duty cycle for electric elements in stoves and ovens;
- For all motors used for mechanical work, we assumed an average load of 60%, except for those used intermittently, such as saws, lathes, sewing machines, and grinders, for which we used 30% -- these assumptions were based on factory observations;
- Where only amperage and voltage were shown on the nameplate, we assumed an 85% power factor -- this is the level required by FEA, but few industries are properly metered.

### Results

Of establishments surveyed, 72% were private limited companies. Sole ownership and public limited companies each accounted for 8% of respondents, partnerships 6%, cooperatives 5%, and public statutory bodies 1%. Two-thirds had more and one-third less than 50% local ownership.

During the survey, 9 of the 76 concerns ceased operations and 10 changed hands. At the beginning of the survey, however, 56% had been established more than 10 years, 16% were established 5-10 years, 11% were established 1-5 years and only one establishment had been in being for less than 1 year (length of ownership data were not obtained on 16%).

Numbers of employees ranged from 2 to 375, with an average of 48. Most concerns employed fewer than 50 people. Only 13% had night shifts; the others closed for the night, sometimes employing a night watchman. Many surveyed establishments were quite small consumers of energy and were mostly, but not wholly, electricity users.

Food manufacturing had both the highest sales figure and highest energy usage per employee (Table 13). However, the proportion of energy cost to sales was also high (8.7%). The survey showed ample room for better energy management in the food manufacturing industry, especially in regard to refrigeration, cooking, and lighting.

Table 13. Employees, sales, and energy costs by industry category.

| Industry type       | Number of employees | Sales (FJD/employee) | Cost per employee (FJD) <sup>a</sup> |          |                 |          |
|---------------------|---------------------|----------------------|--------------------------------------|----------|-----------------|----------|
|                     |                     |                      | All energy                           | Electric | Ancillary fuels | Lighting |
| Food                | 55                  | 74732                | 6480                                 | 1591     | 6               | 55       |
| Miscellaneous       | 37                  | 20244                | 4344                                 | 4095     | 12              | 48       |
| Nonmetallic         | 73                  | 36961                | 2781                                 | 772      | 4               | 27       |
| Chemicals           | 20                  | 56380                | 929                                  | 562      | 5               | 116      |
| Machinery/equipment | 69                  | 18337                | 562                                  | 300      | 7               | 39       |
| Paper/printing      | 30                  | 11320                | 405                                  | 21       | 2               | 29       |
| Wood                | 32                  | 15742                | 366                                  | 170      | 3               | 14       |
| Clothing/footware   | 40                  | 9672                 | 122                                  | 72       | 3               | 29       |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

The clothing sector was lowest in both sales and energy usage per employee. The low energy use was due in part to the judicious mix of manual and electrical machinery and, in part, to the use of individual working lights, rather than over-illuminating whole areas.

Wood manufacturers used least lighting per employee because many of their factories had clear plastic roof panels and high, open doors that let in plenty of natural light.

Several of the owners we interviewed stated that energy was a necessary input and there was little they could do to reduce consumption. They assumed that increases in production and sales meant increases in the use of energy. In fact, however, there was little correlation between sales per employee and energy used per employee. Thus, the cost of lighting was highest in the chemical sector, which does not require as much close work as clothing, wood, food, and some machinery work. This is an obvious area in which savings in energy are possible.

#### Staff energy use

Staff energy uses comprise lighting, office equipment, and such personnel amenities as air conditioning, coffee makers, drink coolers, video sets, etc. Air-conditioning required for industrial purposes is considered separately.

Lighting accounted for an average of 15%, ranging from 1 to 71%, of the electricity used by an industrial establishment. All lighting was electric, except for one instance in which off-premises lighting required 171 L of kerosene per year.

Some establishments have introduced transparent roofing, allowing more natural light into their buildings and reducing the need for

**Table 14.** Average industrial consumption of lighting by employee and area.

|                     | Number of employees | Area of premises (m <sup>2</sup> ) | Energy use (kWh/year) |                    |
|---------------------|---------------------|------------------------------------|-----------------------|--------------------|
|                     |                     |                                    | Per employee          | Per m <sup>2</sup> |
| Food                | 55                  | 1501                               | 350                   | 14                 |
| Miscellaneous       | 37                  | 454                                | 306                   | 15                 |
| Nonmetallic         | 73                  | 311                                | 174                   | 103                |
| Chemicals           | 20                  | 1382                               | 735                   | 7                  |
| Machinery/equipment | 69                  | 1643                               | 248                   | 16                 |
| Paper/printing      | 30                  | 515                                | 184                   | 13                 |
| Wood                | 32                  | 447                                | 88                    | 9                  |
| Clothing/footwear   | 40                  | 635                                | 182                   | 13                 |
| Overall mean        | 47.6                | 1139                               | 321.7                 | 15.6               |

artificial light. The energy used annually for lighting varied a great deal between establishments -- from less than 1 kWh/m<sup>2</sup> to as much as 185 or from 8 to 3339 kWh/employee.

Clothing and wood products industries had lower lighting values both per employee and per square metre (Table 14). The chemicals industry employed relatively few people (average only 20) but was more automated and used a large floor space; accordingly, the lighting value was high per employee but low per square metre. The high lighting energy cost of the nonmetallic sector was largely the result of using powerful security lights over the storage yards at night and on weekends; more efficient security lighting, such as that provided by high-pressure sodium lamps, would be worth considering.

Industrial establishments did not use as much lighting per square metre as the commercial buildings we surveyed, which averaged 98.9 kWh/m<sup>2</sup> per year. However, industries still had room for savings through more efficient lighting, especially security lighting, which used 5% of all lighting energy.

Many of the industrial establishments were already equipped with the most efficient lighting available; 87% of all industrial lighting was by fluorescent tube. The remainder came from incandescent bulbs, which predominated in toilets and corridors and for security lighting.

Office air-conditioning was used in 78% of the industrial establishments and 13% had office with some factory air-conditioning (Table 15); 8% had fans only. The air-conditioning plants were for the protection of machinery (5%), for the benefit of the staff as well as the machinery (28%), or for worker comfort only (67%). The air conditioners were set at 24-27°C in 37% of cases, 21-24°C in 46%, and 18-21°C in 17%. Differences from ambient temperature varied from 1 to 9.5°C.

Only 9% of the systems were large central air conditioners rated at more than 90 kW; most were small ones of less than 50 kW. All were

Table 15. Air-conditioning in industrial establishments.

|                     | Air conditioning in |                        | Mean air-conditioning energy |                    |
|---------------------|---------------------|------------------------|------------------------------|--------------------|
|                     | Office (%)          | Office and factory (%) | kWh/year                     | kWh/m <sup>2</sup> |
| Food                | 73                  | 27                     | 34609                        | 327                |
| Miscellaneous       | 67                  | 0                      | 10588                        | 113                |
| Nonmetallic         | 100                 | 0                      | 5744                         | 42                 |
| Chemicals           | 100                 | 30                     | 10630                        | 90                 |
| Machinery/equipment | 82                  | 6                      | 9099                         | 154                |
| Paper/printing      | 75                  | 0                      | 5386                         | 39                 |
| Wood                | 71                  | 0                      | 1474                         | 101                |
| Clothing/footware   | 67                  | 0                      | 3669                         | 107                |
| All industries      | 78                  | 13                     | 27260                        | 168                |

electric except one that was supplemented with 3600 kg of LPG/year.

The air-conditioning for each establishment consumed annually from 144 to 77,776 kWh and from 5.1 to 664.5 kWh/m<sup>2</sup>. The wide variations between and within groups in mean air-conditioning consumption by industrial category (Table 15) is partly because office areas served by similar size air conditioners vary; also, many small companies switch off their systems during the cool season or during rainy, windy weather in the warm season. Establishments with very high use of air-conditioning per square metre again predominate in the food industry.

Air-conditioning accounted for 10% of spending on electricity in all establishments surveyed; among those that had air-conditioning, it accounted for 13% of their bills.

Office equipment such as typewriters, photocopiers, cash machines, and calculators used only a small part of an establishment's total electricity demand -- only 1.1% of the electricity used for those that used such equipment, and only 0.8% for the whole sample.

Of the establishments surveyed, 84% provided ancillary equipment for the personal needs of workers -- drink coolers, refrigerators, coffee makers, television, etc. All this equipment was electric, but it was supplemented for cooking by LPG in 9% of establishments and by kerosene for cooking in one establishment. Electricity used annually for cooking totaled 147,196 MJ or 5841 kWh/user establishment; LPG was 141,981 MJ or 406 kg/user establishment, and kerosene was 33,284 MJ or 907 L/user establishment.

Ancillary equipment in all establishments surveyed used 100,474 kWh/year of electricity, an average of 1322 kWh/year each. Average annual expenditure per establishment on all forms of energy for this purpose was FJD 240, which was 0.2% of all energy spending by them. Cost per worker for energy for this ancillary equipment was FJD 2-12.

## Productive energy

Electricity had the widest range of uses in our survey -- for cooling, hot air, steam or hot water, direct heat, chemicals production, and mechanical purposes. Industrial diesel oil (IDO) was used for hot air and steam or hot water; automotive diesel oil (ADO) was used for mechanical purposes and, to a small extent, for cooling; industrial fuel oil (IFO) and LPG were both used for hot air, hot water, and steam; kerosene, coke, coal, and waste oil were used for hot air; wood was used for steam and hot water; and oxyacetylene was used for direct heat (welding).

Cooling accounted for 39% of all industrial consumption of electricity. It was always electrical, except when refrigeration was needed in trucks that carried ice cream, frozen meat, and other foods: the diesel oil used for this purpose is included in our transport figures. Cooling temperatures were usually 0 to -15°C, but ice cream and liquefaction of air required temperatures well below that range. Nearly all cooling was used in the storage and processing of foods; the exceptions were storage of rubber at 0 to -10°C and the liquefaction of air and industrial gases.

Of the industries we surveyed, 25% used cooling. Of these, 5% used temperatures of 10-0°C, consuming 14,861 MJ/year per establishment, 89% used temperatures of 0 to -15°C, consuming 11.71 million MJ/year per establishment, and 16% used lower temperatures, consuming 4.89 million MJ/year per establishment. This is obviously an important area in which to pursue improvements in industrial energy management.

Hot air in ovens and furnaces accounted for more use of energy than any other industrial activity. It came from electricity, LPG, kerosene, industrial diesel oil, marine fuel oil, and coke. Of all the establishments surveyed, 24% used fuel to produce air temperatures of 101-600°C, consuming 0.40 million MJ/year per establishment, 7% used fuel to produce air temperatures of 601-1000°C, consuming 0.33 million MJ/year per establishment, and a further 7% used fuel to produce still higher temperatures, consuming 204.38 million MJ/year per establishment. Table 16 shows the temperature ranges, energy sources, and consumption of the four industrial categories that used industrial hot air. Within these four categories, 50% of food establishments used hot air (for baking and roasting), 11% of chemical establishments used it, as did 31% of machinery and equipment establishments (for furnaces, baking metals, and baking paint on metals), and 8% of miscellaneous establishments.

Boilers, except in three establishments that processed vegetable oil, were used to produce either hot water or steam. Of all establishments in the food sector, 78% had boilers, as did 22% in the chemicals sector, 33% in the nonmetallic sector, 13% in the machinery and equipment sector, 33% in the clothing sector, and 8% in the miscellaneous establishments. Overall, 32% of establishments had this used energy to run boilers.

Energy sources included electricity, automotive and industrial diesel oil, LPG, and wood. Temperatures of 60-100°C were required in 74% of boilers, which consumed an average of 91.82 million MJ/year per establishment, and the remainder used temperatures of 101-315°C,

Table 16. Hot air energy use in industrial establishments.

|                     | Temperature<br>(°C) | Energy<br>source <sup>a</sup> | Units/year | Energy<br>(million<br>MJ/year) |
|---------------------|---------------------|-------------------------------|------------|--------------------------------|
| Food                | 101-600             | Electricity                   | 55105 kWh  | 0.198                          |
|                     |                     | LPG                           | 2952 kg    | 0.148                          |
|                     |                     | Kerosene                      | 57101 L    | 2.096                          |
|                     |                     | IDO                           | 106653 L   | 4.149                          |
|                     |                     | All sources                   |            | 6.590                          |
| Chemicals           | 101-600             | Electricity                   | 18486 kWh  | 0.067                          |
| Machinery/equipment | 101-600             | Electricity                   | 146500 kWh | 0.527                          |
|                     |                     | IDO                           | 239 L      | 0.009                          |
|                     | >601                | IDO                           | 42116 L    | 1.638                          |
|                     |                     | IFO                           | 104797 L   | 4.401                          |
|                     |                     | Waste oil                     | 607099 L   | 25.498                         |
|                     |                     | Coke                          | 24800 t    | 992.000                        |
| Miscellaneous       | 101-600             | All sources                   |            | 1021.900                       |
|                     |                     | Electricity                   | 144 kWh    | <0.001                         |

<sup>a</sup> LPG, liquified petroleum gas; IDO, industrial diesel oil; IFO, industrial fuel oil.

consuming an average 31.59 million MJ/year per establishment. Table 17 shows details of boiler energy demand industry by industry.

We considered the application of direct heat in operations such as welding, plastic sealing, ironing, and forging separately. Although this is not a major use of industrial energy in Suva (Table 18), it is widespread. Of the establishments in the food sector, 73% used direct heat, as did 67% in the clothing and footwear sector, 57% in the wood products sector, 25% in the paper and printing sector, 56% in the chemicals sector, 67% in the nonmetallic sector, 63% in the machinery sector, and 33% in the miscellaneous sector.

Energy for chemical processes was used by 14 of the surveyed establishments for such purposes as electrolysis of water, plastic formation, battery charging, photoprocessing, and vulcanizing rubber. Of establishments in the food sector, 9% used energy for this purpose; electrolysis accounted for 32,624 MJ/year and battery charging for 28,643 MJ/year. In the paper and printing sector, 75% used energy for a chemical process (photoprocessing) using 24,074 MJ/year. In the chemicals sector, 33% of establishments used energy for chemical processing -- vulcanizing rubber accounted for 83,097 MJ/year and the manufacture of polyethylene accounted for 32,080 MJ/year. Of the machinery and equipment establishments, 25% used energy for chemical processes -- 11,448 MJ/year for battery charging and 224,349 MJ/year for rectifiers. Among the miscellaneous group, 17% used 28,383 MJ/year, all for photoprocessing. For all surveyed establishments, 464,698 MJ/year was expended on chemical processes, an average for the 14 actual users of 33,193 MJ/year per establishment.

Table 17. Temperature ranges and energy use for industrial boilers.

|                     | Temperature<br>(°C) | Energy<br>source <sup>a</sup> | Units/year | Energy<br>(million<br>MJ/year) |
|---------------------|---------------------|-------------------------------|------------|--------------------------------|
| Food                | 60-100              | Electricity                   | 563933 kWh | 2.03                           |
|                     |                     | LPG                           | 3891 kg    | 0.19                           |
|                     |                     | IDO                           | 808085 L   | 31.43                          |
|                     |                     | IFO                           | 803687 L   | 33.76                          |
|                     |                     | Total                         |            | 67.41                          |
|                     | 101-315             | Electricity                   | 20814 kWh  | 0.07                           |
|                     |                     | IDO                           | 113536 L   | 4.42                           |
|                     |                     | IFO                           | 573475 L   | 22.61                          |
|                     |                     | Total                         |            | 27.10                          |
| Chemicals           | 60-100              | IDO                           | 2536 L     | 0.11                           |
|                     |                     | Electricity                   | 19500 kWh  | 0.07                           |
|                     |                     | Total                         |            | 0.18                           |
| Nonmetallic         | 60-100              | Electricity                   | 6266 kWh   | 0.02                           |
|                     |                     | IDO                           | 147894 L   | 5.75                           |
|                     |                     | IFO                           | 322313 L   | 13.54                          |
|                     |                     | Wood                          | 232309 kg  | 4.55                           |
|                     |                     | Total                         |            | 23.86                          |
| Machinery/equipment | 60-100              | Kerosene                      | 5103 L     | 0.19                           |
|                     |                     | Electricity                   | 1078 kWh   | <0.01                          |
|                     |                     | Total                         |            | 0.19                           |
| Clothing/footwear   | 60-100              | IDO                           | 4500 L     | 0.18                           |
| Miscellaneous       | 101-315             | IDO                           | 115515 L   | 4.49                           |
| Total all industry  |                     |                               |            | 123.41                         |

<sup>a</sup> LPG, liquified petroleum gas; IDO, industrial diesel oil; IFO, industrial fuel oil.

By far the most common use of electrical energy in industry was mechanical work (Table 19) -- activities from cutting bread to sawing logs, including pumping, compression, cutting, grinding, sewing, polishing, mixing, blowing, and pounding. However, we have not included in this category mechanical processes such as forging and high-temperature gas cutting that also involved heat. The mechanical energy was electric except that one establishment used diesel pumps and another used diesel and gasoline to run compressors and pumps.

A useful indicator of how efficiently a process uses energy is obtained by calculating the amount of energy required for a given unit of production. Response to our requests for data was poor, but we were able to make calculations for some types of production. Energy (in MJ) used per kilogram of production in bread baking was 2.8 (5.1 including transport), in coconut oil 0.9 (1.4), in concrete blocks 0.6

Table 18. Energy use for industrial direct heat applications.

|                     | Energy source <sup>a</sup> | Per establishment (MJ/year) | Total million (MJ/year) |
|---------------------|----------------------------|-----------------------------|-------------------------|
| Food                | Electricity                | 38683                       | 0.62                    |
|                     | Oxyacetylene               | 5834                        | 0.09                    |
|                     | Diesel                     | 4515                        | 0.07                    |
|                     | LPG                        | 3750                        | 0.06                    |
|                     | Total                      |                             | 0.84                    |
| Clothing/footwear   | Electricity                | 6129                        | 0.01                    |
|                     | LPG                        | 1560                        | <0.01                   |
|                     | Total                      |                             | 0.02                    |
| Wood                | Electricity                | 24234                       | 0.10                    |
|                     | Oxyacetylene               | 30535                       | 0.12                    |
|                     | Diesel                     | 38880                       | 0.16                    |
|                     | Total                      |                             | 0.37                    |
| Paper/printing      | Electricity                | 3856                        | <0.01                   |
| Chemicals           | Electricity                | 16073                       | 0.08                    |
|                     | LPG                        | 520                         | <0.01                   |
|                     | Total                      |                             | 0.08                    |
| Nonmetallic         | Electricity                | 14880                       | 0.03                    |
|                     | Oxyacetylene               | 8270                        | 0.02                    |
|                     | Total                      |                             | 0.05                    |
| Machinery/equipment | Electricity                | 149402                      | 1.49                    |
|                     | Oxyacetylene               | 15469                       | 0.15                    |
|                     | LPG                        | 15600                       | 0.16                    |
|                     | Coal (forge)               | 10719                       | 0.11                    |
|                     | Total                      |                             | 3.31                    |
| Miscellaneous       | Electricity                | 54                          | <0.01                   |
|                     | Oxyacetylene               | 3927                        | 0.02                    |
|                     | LPG                        | 7700                        | 0.03                    |
|                     | Total                      |                             | 0.05                    |
| Total all industry  |                            |                             | 4.73                    |

<sup>a</sup> LPG, liquified petroleum gas.

(2.5), and in edible oil products 4.0 (4.2). For production in brewing, it was 1.4 MJ/L (1.5 including transport) and in soft drinks 0.4 (0.7). In tire retreading, energy use was 124.5 MJ/tire (168.4 with transport), and in shoe manufacturing 0.9 MJ/pair of shoes (no data were available for transport energy used).

These figures cannot readily be compared to those of another country unless the processes are similar. However, they can be useful

Table 19. Energy use for industrial mechanical processes.

|                     | Energy source <sup>a</sup> | % of users | Per establishment (MJ/year) | Total (million MJ/year) |
|---------------------|----------------------------|------------|-----------------------------|-------------------------|
| Food                | Electricity                | 100        | 1182073                     | 26.01                   |
|                     | ADO                        | 5          | 2334000                     | 2.33                    |
| Clothing/footware   | Electricity                | 100        | 19146                       | 0.06                    |
| Wood                | Electricity                | 100        | 69479                       | 0.49                    |
| Paper/printing      | Electricity                | 100        | 67118                       | 0.27                    |
| Chemicals           | Electricity                | 100        | 150196                      | 1.35                    |
| Nonmetallic         | Electricity                | 100        | 179423                      | 0.36                    |
| Machinery/equipment | Electricity                | 94         | 237114                      | 3.79                    |
|                     | ADO                        | 6          | 691200                      | 0.69                    |
|                     | Gasoline                   | 6          | 22853                       | 0.02                    |
| Miscellaneous       | Electricity                | 82         | 245292                      | 2.70                    |
| Total               |                            |            |                             | 38.07                   |

<sup>a</sup> ADO, automotive diesel oil.

in monitoring the progress of any energy-saving program that may be instituted.

#### Transport energy

We differentiated between transport of goods within the premises, as for instance by conveyor belt or forklift truck, and transport outside the factory (Table 20). The latter included travel of establishment personnel in company cars run at company expense. Thus, all transport fuel directly purchased by the establishment was included. However, we did not include fuel used by companies contracted to transport the goods of the establishments surveyed as we did not have the time or survey personnel available to do so.

The most common energy source for internal transport was electricity (Table 20), which was used for cranes, conveyor belts, and winches. LPG, automotive diesel oil, and gasoline were used for forklifts and cranes. Nonmetallic industries had the highest use of energy for on-site transportation.

#### Other uses of energy

Uses of energy for purposes other than discussed above are classified as "other," and are summarized in Table 21. This classification includes fuel for standby electricity generators, and energy used for laboratory equipment and such equipment as vacuum cleaners and polishers.

Table 20. Fuels used industrially in transport.

| On-premises transport |                                |                           |                                   | Off-premises transport |                           |                               |                                   |
|-----------------------|--------------------------------|---------------------------|-----------------------------------|------------------------|---------------------------|-------------------------------|-----------------------------------|
| Users<br>(%)          | Source <sup>a</sup>            | Total<br>(MJ/year)        | Per<br>establishment<br>(MJ/year) | Users<br>(%)           | Fuels <sup>a</sup>        | Total<br>(million<br>MJ/year) | Per<br>establishment<br>(MJ/year) |
| 45                    | Electricity<br>LPG<br>ADO      | 407383<br>227500<br>42362 | 40738<br>22750<br>4236            | 82                     | ADO<br>Gasoline           | 12.33<br>8.53                 | 685918<br>474116                  |
| 33                    | Electricity                    | 242                       | 242                               |                        |                           |                               |                                   |
| 14                    | Electricity                    | 39459                     | 39459                             | 86                     | ADO                       | 1.52                          | 252521                            |
| 25                    | Electricity                    | 1289                      | 1289                              | 75                     | ADO<br>Gasoline           | 0.40<br>1.00                  | 133565<br>333714                  |
| 33                    | Electricity<br>ADO<br>Gasoline | 1714<br>453696<br>42415   | 571<br>151232                     | 89                     | ADO<br>Gasoline           | 1.37<br>2.10                  | 171579<br>261876                  |
| 67                    | Electricity<br>ADO             | 286239<br>1252838         | 143120<br>626419                  | 67                     | ADO<br>Gasoline           | 8.15<br>1.34                  | 4073741<br>671060                 |
| 75                    | Electricity<br>ADO             | 295143<br>392848          | 24595<br>32737                    | 88                     | ADO<br>Gasoline<br>Premix | 5.72<br>4.38<br>0.21          | 408442<br>312672<br>15165         |
| 25                    | Electricity                    | 1124                      | 375                               | 50                     | ADO<br>Gasoline           | 2.72<br>1.41                  | 452878<br>234971                  |

<sup>a</sup> LPG, liquified petroleum gas; ADO, automotive diesel oil.

**Table 21.** Energy use for "other" purposes in industrial establishments.

|                     | Users<br>(%) | Energy source <sup>a</sup> | Per<br>establishment<br>(MJ/year) | Total<br>(MJ/year) |
|---------------------|--------------|----------------------------|-----------------------------------|--------------------|
| Food                | 32           | Electricity                | 24755                             | 173287             |
|                     |              | LPG                        | 7914                              | 55400              |
|                     |              | ADO                        | 85640                             | 599479             |
|                     |              | IDO                        | 113750                            | 796250             |
| Wood                | 29           | Electricity                | 7668                              | 15335              |
| Paper/printing      | 25           | Electricity                | 42768                             | 42768              |
| Chemicals           | 22           | Electricity                | 170                               | 339                |
| Nonmetallic         | 33           | Gasoline                   | 27520                             | 27520              |
|                     |              | Kerosene                   | 29360                             | 29360              |
| Machinery/equipment | 13           | Electricity                | 1874                              | 3747               |
|                     |              | ADO                        | 18870                             | 37740              |
| Miscellaneous       | 25           | Electricity                | 48                                | 145                |
|                     |              | ADO                        | 6483                              | 19450              |
| Total               |              |                            |                                   | 1800820            |

<sup>a</sup> LPG, liquified petroleum gas; ADO, automotive diesel oil; IDO, industrial diesel oil.

### Summary

Total industrial use of energy in the surveyed establishments was 1,272,647 GJ/year, of which 96.4% was for production purposes, 3.1% for transport and "other" uses, and 0.5% for staff use. Of the production energy, 84% was for hot air, notably furnaces, and 10% for hot water.

Coal provided most of the energy expended, being mostly used for hot-air production. Electricity, however, was important because of the wide range of uses to which it was applied. The use of industrial diesel oil and industrial fuel oil for boilers is worth examining -- indeed, some industries are already beginning to substitute wood for these imported fuels. Wood replacement for coal (which is also imported) is also worth examination.

## THE COMMERCIAL USE OF ENERGY

The commercial sector includes office buildings, stores, commercial buildings, restaurants, garages and service stations, hotels, motels, dormitories, and various educational, recreational, and social institutions. Offices are dealt with subsequently. Here we deal with service centres, shops, catering places and recreational, residential (including hotel), educational, and "unique" buildings.

### Methods

Commercial establishments were identified from the "yellow pages" of the Suva telephone directory and we chose a sample of 133 by selecting randomly every third establishment on the list. We then wrote to each of those selected asking for their cooperation in the survey and attaching a questionnaire. This was followed by a telephone call asking that a survey team visit the premises. The final sample, after eliminating refusals and concerns that were no longer in operation, was 77 (Table 22).

We used two types of questionnaire. The first sought information common to all the commercial sector -- details of type of ownership, whether leasehold or freehold, period of operation, operating times, the accounting year, staff, sales, consumption of different kinds of energy, area of premises, lighting, air-conditioning, water consumption, and any achievements in energy conservation. The second was specific for the type of business; it sought details on energy uses and waste management.

Each establishment was visited by a survey team for 30 minutes to 2 hours or more, depending on its size. The team estimated energy consumption for each end use, using the methods and assumptions described for the industrial sector. Survey estimates of nonelectricity use were checked against company accounts. Estimates of the

Table 22. Commercial establishments in survey.

|                         | Listed | Selected | Surveyed |
|-------------------------|--------|----------|----------|
| Shops                   | 168    | 56       | 26       |
| Educational             | 56     | 15       | 15       |
| Residential             | 54     | 17       | 10       |
| Recreational            | 45     | 15       | 9        |
| Catering establishments | 38     | 13       | 8        |
| Service centres         | 42     | 14       | 7        |
| Unique buildings        | 3      | 3        | 3        |

use of electricity were checked against FEA accounts, which showed a mean deviation of about 13.6% (0.1-37%).

### Results

All establishments surveyed were at least 50% locally owned: 30% were partnerships, 28% nonprofit private organizations, 22% sole proprietorships, 18% private limited companies, and 2% cooperative. Most (60%) had been in operation more than 10 years, 23% 5-10 years, 15% 1-5 years, and 2% less than 1 year. Of the surveyed establishments, 57% operated more than 10 hours/day; 22% operated Monday to Friday, 31% Monday to Saturday, and 47% 7 days/week.

The floor area per establishment ranged from 13 m<sup>2</sup> to more than 3500 m<sup>2</sup> but almost 50% were between 100 and 1000 m<sup>2</sup> (Fig. 17).

Electricity was the most important source of energy in the establishments surveyed and was used by all of them, although most establishments consumed less than 63,492 kWh/year of electricity, costing less than FJD 10,000 (Fig. 18). Electricity accounted for 65% of all energy costs for the sector or, excluding transport fuel, 89%. Diesel oil for transport was used by 21% of establishments and accounted for 11% of total energy costs. Gasoline for transport was used by 50% and accounted for 16% of total energy costs. Industrial diesel oil was used by 5% of establishments for laundry operations and in boilers; it accounted for 3% of total energy costs and 4% of total nontransport energy costs. LPG was used by 42% of establishments, for cooking and in school laboratories, and it accounted for 3% of total energy costs and 4% of total nontransport energy costs. Kerosene was

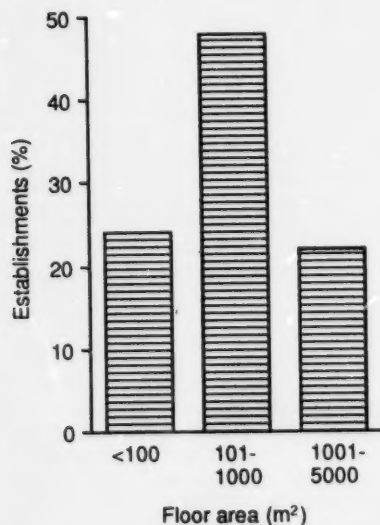


Fig. 17. Floor area of surveyed commercial establishments.

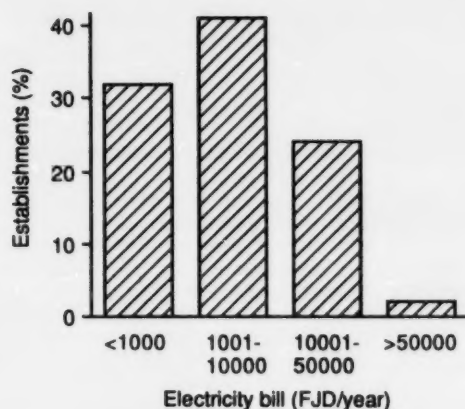


Fig. 18. Annual expenditure on electricity of surveyed commercial establishments. In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

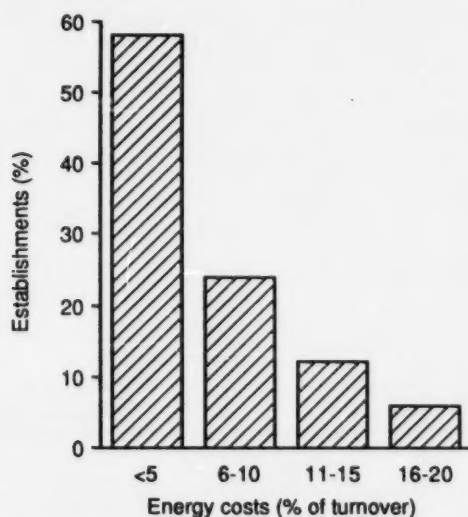


Fig. 19. Distribution of energy cost as percentage of turnover.

used by 20% of surveyed establishments, for cooking and steam cleaning; it accounted for 2% of total energy costs and 3% of total nontransport energy costs. Other fuels were used by 18% of the establishments -- premix for mowing, wood for cooking, and acetylene for welding; together they accounted for 1% of total energy costs in the commercial sector. For all the surveyed establishments, transport took 27% of the spending on energy.

Energy costs averaged FJD 11,594/year, or 5.2% of turnover; indeed, almost 60% of establishments kept their energy costs to less than 5% of turnover (Fig. 19). The exceptions were in the hotel and catering business.

Commercial establishments made use of the versatility of electricity, using other fuels only where more practical, as for transport, or cheaper, as in cooking (Table 23). The heaviest demand for energy came from transport, followed by air-conditioning, refrigeration, and cooking.

We discuss below the groups that, because they are more numerous or greater users of energy, are more important. They are laundries, automotive service stations, food and nonfood shops, catering places, recreation centres, residential establishments, educational establishments, and unique establishments.

### Laundries

Nine laundries were listed in the yellow pages, of which we surveyed three. Two had annual turnovers of less than FJD 100,000, but the third had a turnover well over FJD 500,000, for a mean annual turnover of FJD 220,000. On average, they had total energy costs of FJD 16,831 (7.6% of average turnover), which was broken down into gasoline, FJD 9123 (4.1% of average turnover); industrial diesel oil, FJD 5633 (2.6%); electricity, FJD 1882 (0.9%); LPG, FJD 130 (0.1%); and kerosene, FJD 63 (<0.1%).

For transport, the laundries used, annually on average, 18,950 L of gasoline (651,880 MJ); for ironing, steam pressing, and cleaning, 4366 kWh of electricity, 1333 L of IDO, and 126 kg of LPG (73,872 MJ); for washing and drying, 5442 kWh of electricity (19,591 MJ); for cooking starch, 146 L of kerosene (5358 MJ); for "other" uses, 944 kWh of electricity (3398 MJ); and for lighting, 251 kWh of electricity (904 MJ). Thus, the laundries surveyed used on average 755,003 MJ/year each.

### Automotive service stations

The yellow pages listed 15 "service stations" of which we approached 5 and actually surveyed 4. The survey showed that annually, they averaged 18,135 kWh of electricity (65,286 MJ) for mechanical purposes; 7745 kWh of electricity (27,882 MJ) for lighting; 7513 kWh of electricity (27,047 MJ) for air-conditioning; 526 L of kerosene (19,304 MJ) for steam cleaning; 3168 kWh of electricity (11,405 MJ) for cooking; 1941 kWh of electricity (6987 MJ) for refrigeration; 675 kWh of electricity (2432 MJ) for battery charging; 547 kWh of electricity (1969 MJ) for office use; 23 m<sup>3</sup> of oxyacetylene (932 MJ) for welding; and 173 kWh of electricity (623 MJ) for vulcanizing. In total, each establishment averaged 163,865 MJ/year.

Mechanical processes, air-conditioning, and lighting are obvious areas where energy might be saved.

### Food shops

We surveyed 8 of the 44 listed food shops, which were classified as fruit and grocery stores, supermarkets, meat and fish stores, and

Table 23. Uses and annual consumption of fuels in commercial establishments.

|                    | Energy by source (GJ/year) <sup>a</sup> |              |              |            |             |             |            |            | Per<br>establishment<br>(MJ) |                        |        |
|--------------------|-----------------------------------------|--------------|--------------|------------|-------------|-------------|------------|------------|------------------------------|------------------------|--------|
|                    | Electricity                             | ADO          | Gasoline     | IDO        | LPG         | Kerosene    | Premix     | Wood       |                              | Oxy-<br>acety-<br>lene | Total  |
| Lighting           | 1334                                    |              |              |            |             |             |            |            |                              | 1334                   | 17326  |
| Air-conditioning   | 4153                                    |              |              |            |             |             |            |            |                              | 4153                   | 53942  |
| Office equipment   | 123                                     |              |              |            |             |             |            |            |                              | 123                    | 1591   |
| Fans               | 551                                     |              |              |            |             |             |            |            |                              | 551                    | 7163   |
| Refrigeration      | 3693                                    |              |              |            |             |             |            |            |                              | 3693                   | 47965  |
| Cooking            | 512                                     |              |              |            | 1118        | 1122        |            | 551        |                              | 3303                   | 42896  |
| Steam/hot water    | 928                                     |              |              | 164        | 198         | 86          |            |            |                              | 1376                   | 17870  |
| Welding/ironing    | 8                                       |              |              |            |             |             |            |            | 1                            | 9                      | 119    |
| Chemical           | 1                                       |              |              |            |             |             |            |            |                              | 1                      | 16     |
| Laundry/washing    | 61                                      |              |              |            |             |             |            |            |                              | 61                     | 797    |
| Mechanical         | 345                                     |              |              |            |             |             | 200        |            |                              | 871                    | 11313  |
| Audiovisual        | 352                                     |              | 23           |            |             |             |            |            |                              | 352                    | 4577   |
| Communication      | 1338                                    |              |              |            |             |             |            |            |                              | 1338                   | 17371  |
| Transport          |                                         | 2901         | 8073         | 482        |             |             |            |            |                              | 11456                  | 148784 |
| Other              | 129                                     | 604          |              |            |             |             |            |            |                              | 733                    | 9519   |
| Total <sup>b</sup> | 13528<br>(46)                           | 3808<br>(13) | 8096<br>(28) | 646<br>(2) | 1316<br>(4) | 1208<br>(4) | 200<br>(1) | 551<br>(2) | 1<br>( $<1$ )                | 29354                  | 381249 |

<sup>a</sup> ADO, automotive diesel oil; IDO, industrial diesel oil; LPG, liquified petroleum gas.

<sup>b</sup> Values in parentheses are percentages of total energy use.

general groceries. Of these, the large ones delivered goods and thus incurred transport costs. The food shops had a mean annual turnover of FJD 1.03 million, of which 1.39% (FJD 14,363) was energy costs. This breaks down as: electricity FJD 8235 (0.8% of turnover), ADO FJD 4420 (0.4%), gasoline FJD 1630 (0.2%), and LPG FJD 69 (<0.1%).

For each establishment, transport annually accounted for 4320 L of ADO and 3464 L of gasoline (285,050 MJ); refrigeration, 9126 kWh of electricity (32,854 MJ); cooking, 2122 kWh of electricity and 304 kg of LPG (22,839 MJ); lighting, 3578 kWh of electricity (12,881 MJ); mechanical purposes, 2385 kWh of electricity (8586 MJ); offices, fans, etc., 1337 kWh of electricity (4813 MJ); air-conditioning, 447 kWh of electricity (1609 MJ); and balances, 16 kWh of electricity (58 MJ). The total was 368,690 MJ/year each.

Thus, lighting and cooking would repay attention in an energy-management program.

### **Nonfood shops**

The nonfood shops had a mean annual turnover of FJD 340,687. Mean energy cost was FJD 2947 (0.9% of turnover), broken down into gasoline FJD 1688 (0.5%), electricity FJD 764 (0.2%), ADO FJD 481 (0.1%), oxyacetylene FJD 7 (<0.1%), and LPG FJD 3 (<0.1%).

Within each establishment, transport annually accounted for 1017 L of ADO and 3805 L of gasoline (169,945 MJ); lighting for 2351 kWh of electricity (8464 MJ); air-conditioning for 1235 kWh of electricity (4446 MJ); "other" uses including fans and office machinery for 1106 kWh of electricity (3982 MJ); mowing for 30 L of gasoline (1032 MJ); mechanical purposes for 199 kWh of electricity (716 MJ); cooking for 119 kWh of electricity and 3 kg of LPG (578 MJ); refrigeration for 146 kWh of electricity (526 MJ); and welding for 1 m<sup>3</sup> acetylene (41 MJ) for a total of 189,730 MJ.

### **Catering establishments**

The directory listed 28 catering places -- restaurants, snack and milk bars, and small takeaway (takeout) and bakery businesses -- of which we surveyed 8. As in the domestic sector, cooking and food warming were performed with a variety of fuels -- kerosene (75% of establishments), LPG (88%), and electricity (88%).

Mean annual turnover was FJD 146,384 and 5.5% of that value (FJD 8058) was spent on energy. Electricity accounted for FJD 5166 (3.5% of turnover), kerosene FJD 1655 (1.1%), LPG FJD 870 (0.6%), gasoline FJD 239 (0.2%), and ADO FJD 130 (0.1%).

On the basis of individual establishments, cooking annually consumed 7833 kWh of electricity, 473 kg of LPG, and 3588 L of kerosene (183,529 MJ); refrigeration, 11,606 kWh of electricity (41,782 MJ); transport, 317 L of ADO and 442 L of gasoline (27,378 MJ); air-conditioning, 3726 kWh of electricity (13,414 MJ); lighting, 2449 kWh of electricity (12,416 MJ); hot water, 2398 kWh of electricity (8633 MJ); "other" uses, including fans and office equipment, 1464 kWh of electricity (5270 MJ); electronics, 357 kWh of electricity (1285 MJ); hot air, 91 kWh of electricity (328 MJ); and mechanical purposes, 60 kWh of electricity (216 MJ) for a total of 294,251 MJ.

### Recreational centres

Recreational centres include churches, theatres, nightclubs, and game centres. The yellow pages listed 45, of which we surveyed 8. The greatest energy demand in this sector is for air-conditioning, because of heavy use by the theatres, which also use electricity for fans and projection. Electronic games in amusement centres do not consume much electricity.

Mean annual turnover was FJD 344,704, and energy cost 1.8% of this amount, or FJD 6186. The breakdown was: electricity FJD 5881 (1.7% of turnover), gasoline FJD 248 (0.1%), wood FJD 94 (<0.1%), LPG FJD 30 (<0.1%), and kerosene FJD 27 (<0.1%).

Per establishment, air-conditioning consumed 46,336 kWh of electricity (166,810 MJ); cooking 27 kWh of electricity, 62 L of kerosene, 29 kg of LPG, and 2 t of wood (42,922 MJ); audiovisual 11,344 kWh of electricity (40,838 MJ); lighting 5052 kWh of electricity (18,187 MJ); transport 458 L of gasoline (15,755 MJ); fans 1118 kWh of electricity (4025 MJ); refrigeration 1038 kWh of electricity (3737 MJ); "other" uses 725 kWh of electricity (2610 MJ); hot water 188 kWh of electricity (677 MJ); and games 9 kWh of electricity (32 MJ) for a total of 295,593 MJ.

### Residential establishments

Residential establishments were those that, as a business, offered lodgings -- hotels, motels, and guest houses. Of the 54 listed, we surveyed 10. Lighting, air conditioning, and cooking were the major uses for energy. Energy-saving measures in refrigeration, air-conditioning, hot water, and lighting could have a substantial effect on the energy demand of these establishments.

Their mean annual turnover was FJD 240,000. Mean energy spending was FJD 17,975 (7.5% of turnover), broken down into electricity FJD 16,370 (6.8%), LPG FJD 920 (0.4%), gasoline FJD 528 (0.2%), marine diesel oil FJD 693 (0.3%), ADO FJD 137 (0.1%), premix FJD 59 (0.1%), and kerosene FJD 20 (0.1%).

Per establishment, refrigeration annually consumed 78,370 kWh of electricity (282,132 MJ); air-conditioning 42,630 kWh of electricity (153,468 MJ); hot water 22,774 kWh of electricity (81,986 MJ); cooking 2739 kWh of electricity, 47 L of kerosene, and 894 kg of LPG (56,286 MJ); boat transport 1238 L of marine diesel oil (48,158 MJ); lighting 8107 kWh of electricity (29,185 MJ); transport 407 L of gasoline and 355 L of ADO (27,634 MJ); "other" uses 5973 kWh of electricity (21,503 MJ); fans 4639 kWh of electricity (16,700 MJ); mowing 71 L of premix (2393 MJ); office uses 172 kWh of electricity (619 MJ); and laundry 27 kWh of electricity (97 MJ) for a total of 720,161 MJ.

### Educational establishments

Educational establishments included boarding and day schools or teaching centres. Of the 56 listed, 15 were finally surveyed. Energy needs varied widely, depending on the services offered by the institution. For instance, all primary day schools needed only a small amount of energy for electric lighting, office equipment, and perhaps

a kettle. Secondary schools that offered industrial arts and home economics courses needed more energy for the relevant teaching equipment than those that offered only academic subjects. Boarding institutions needed the most energy because of the hostel facilities.

Mean annual energy costs for the surveyed establishments were FJD 2374, consisting of FJD 1418 for electricity, FJD 431 for LPG, FJD 235 for gasoline, FJD 181 for ADO, FJD 112 for premix, FJD 14 for kerosene, and FJD 9 for wood. The survey showed that reductions in the use of energy can be achieved in cooking and lighting.

Per establishment, cooking annually consumed 1011 kWh of electricity, 385 kg of LPG, 31 L of kerosene, and 714 kg of wood (37,987 MJ); mowing 437 L of ADO and 286 L of premix (26,419 MJ); fans 4610 kWh of electricity (16,596 MJ); lighting 3831 kWh of electricity (13,792 MJ); hot water 2986 kWh of electricity (10,750 MJ); transport 217 L of gasoline (7465 MJ); refrigeration 1804 kWh of electricity (6494 MJ); laboratories and workshops 931 kWh of electricity and 45 kg of LPG (5602 MJ); "other" uses 744 kWh of electricity (2678 MJ); ironing 356 kWh of electricity (1282 MJ); and office uses 157 kWh of electricity (565 MJ) for a total of 129,630 MJ.

#### Unique establishments

Finally, we surveyed two establishments that were unique in their functions. One was the national radio establishment; the other is not described for reasons of confidentiality, but the figures below include data from it. Both establishments made substantial use of electronic equipment. Mean annual energy cost was FJD 68,591, which was 10% of turnover. Of this, electricity accounted for FJD 53,923 (7.8% of turnover; but this value does not include self-generated electricity), gasoline FJD 11,443 (1.7%), and ADO FJD 3225 (0.5%).

Per establishment annually, transport consumed 21,191 L of gasoline (728,970 MJ); communication 180,951 kWh of electricity (651,424 MJ); air-conditioning 121,185 kWh of electricity (436,266 MJ); "other" uses 7866 L of ADO (302,054 MJ); lighting 27,049 kWh of electricity (97,376 MJ); fans 2967 kWh of electricity (10,681 MJ); cooking 2600 kWh of electricity (9360 MJ); audiovisual 2298 kWh of electricity (8273 MJ); office use 2242 kWh of electricity (8071 MJ); and refrigeration 2054 kWh of electricity (7394 MJ) for a total of 2,259,870 MJ.

#### Summary

The total energy used per year by the surveyed commercial establishments was 381,249 MJ of which 39% was for transport, 14% for air-conditioning, 13% for refrigeration, 11% for cooking, 5% for hot water and steam, 5% for lighting, 5% for communication, and the balance for mechanical, fans, office, chemical, ironing, recreation, audiovisual, welding, and other uses.

As in industrial establishments, electricity's versatility resulted in its utilization for the widest range of end uses contributing to 46% for all energy used by the commercial sector. Motor spirit, largely used for transport, contributed 27.6% while the third largest energy contributor, automotive diesel oil contributed

13%. Other sources -- LPG, kerosene, industrial diesel, wood, premix, and oxyacetylene -- contributed the balance.

It is clear that energy conservation measures should focus on transport, air-conditioning, refrigeration, and cooking within the commercial sector.

## THE USE OF ENERGY IN SELECTED COMMERCIAL BUILDINGS

The project team surveyed a selection of Suva's high-rise buildings in addition to the survey of different commercial concerns previously described.

We contacted the owners of 14 buildings that had three or more stories to see whether they would agree to an energy survey of their buildings. Four did not respond, but 10 agreed, from whom we selected 8. The team also surveyed two government buildings, making 10 in all. To protect the confidentiality of data, the buildings are referred to below by code number.

Of the 10 buildings selected, 9 were office blocks and 1 had extensive printing equipment. Two had arcades of shops on the ground floor, whereas the others all had ground-floor offices. Details of the numbers of floors, occupancy, air conditioning, and elevators are in Table 24.

### Methods

On receipt of permission to survey a building, the team consulted the architect or architects and the City Council's building section for building plans and to get information on physical characteristics such as materials, insulation, window shading, air-conditioning, plant location, orientation to sun and wind, etc.

We then notified the tenants and arranged survey visits, which were carried out in April and May 1982 by a team of four students under the project leader. Typically, 1-2 days were spent in each building recording the equipment installed, its hours of use, the number of occupants, climatic conditions, and arrangements for billing power between tenant and landlord. FEA provided details of each tenant's electricity bill. After the survey, the team spent several weeks estimating the use in the buildings of electricity (the predominant fuel) from survey records of equipment power rating, hours of use, and assumptions of load factors. We also contacted the maintenance contractors for air conditioners and elevators to establish equipment specifications and hours of use.

### Results

All the buildings used only electricity except for one in which some cooking was done with LPG in a ground-floor restaurant. This was minor in comparison to the total energy consumption of the building and therefore is ignored. This report deals only with use of electricity, which is summarized for 1981 and 1982 in Table 25.

The 1981 figures were compiled from FEA records; those for 1982 were obtained by comparing FEA records for the first quarter or half

Table 24. Main features of commercial buildings surveyed.

|    | Air-conditioning <sup>a</sup> | Elevator | Number of floors | Floor area (m <sup>2</sup> ) | Number of occupants | Area per occupant (m <sup>2</sup> ) |
|----|-------------------------------|----------|------------------|------------------------------|---------------------|-------------------------------------|
| C1 | Central                       | Yes      | 3-5              | 2150                         | 180                 | 12                                  |
| C2 | Both                          | Yes      | > 5              | 4900                         | 280                 | 18                                  |
| C3 | Central                       | Yes      | > 5              | 9060                         | 450                 | 20                                  |
| P1 | Both                          | No       | 3-5              | 2620                         | 185                 | 14                                  |
| P2 | Central                       | Yes      | > 5              | 4250                         | 340                 | 13                                  |
| P3 | Room                          | No       | 3-5              | 2150                         | 110                 | 20                                  |
| P4 | Central                       | Yes      | > 5              | 3750                         | 230                 | 16                                  |
| P5 | Room                          | No       | 3-5              | 1350                         | 80                  | 17                                  |
| G1 | Central                       | Yes      | 3-5              | 3850                         | 190                 | 20                                  |
| G2 | Central                       | No       | 1-2              | 3950                         | 150                 | 26                                  |

<sup>a</sup> Where there are both room air conditioners and a central system, the former is usually a standby device to protect sensitive instruments.

Table 25. Annual electricity consumption, surveyed commercial buildings, 1981 and 1982.

|                                            | MWh/year |      | Cost<br>(FJD 000/year) <sup>a</sup> |      | kWh/m <sup>2</sup> |      | FJD/m <sup>2</sup><br>(1982) | kWh/<br>occupant<br>(1982) |
|--------------------------------------------|----------|------|-------------------------------------|------|--------------------|------|------------------------------|----------------------------|
|                                            | 1981     | 1982 | 1981                                | 1982 | 1981               | 1982 |                              |                            |
|                                            |          |      |                                     |      |                    |      |                              |                            |
| Buildings with central air-conditioning    |          |      |                                     |      |                    |      |                              |                            |
| C1                                         | 314      | 333  | 47                                  | 52   | 146                | 155  | 24.3                         | 1850                       |
| C2                                         | 894      | 798  | 132                                 | 126  | 183                | 163  | 25.7                         | 2830                       |
| C3                                         | 1445     | 1508 | 212 <sup>b</sup>                    | 238  | 159                | 166  | 26.3                         | 3360                       |
| P1                                         | 320      | 368  | 43                                  | 58   | 122                | 140  | 22.1                         | 2010                       |
| P2                                         | 739      | 888  | 109 <sup>b</sup>                    | 140  | 174                | 209  | 32.9                         | 2590                       |
| P4                                         | 534      | 540  | 78 <sup>b</sup>                     | 85   | 142                | 144  | 22.7                         | 2370                       |
| G1                                         | na       | 307  | na                                  | 48   | na                 | 79   | 12.5                         | 1615                       |
| G2                                         | 1637     | 1638 | 251                                 | 258  | 414                | 415  | 65.3                         | 10900                      |
| Buildings without central air-conditioning |          |      |                                     |      |                    |      |                              |                            |
| P3                                         | 202      | 255  | 31 <sup>c</sup>                     | 40   | 94                 | 118  | 19.7                         | 2280                       |
| P5                                         | 54       | 56   | 8 <sup>c</sup>                      | 9    | 40                 | 42   | 6.6                          | 700                        |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

<sup>b</sup> Based on 14.7 t/kWh.

<sup>c</sup> Based on 15.4 t/kWh.

of 1982 with the equivalent records for 1981. G1, a government building, was not metered separately in 1981, but its consumption probably did not change between 1981 and 1982. For the other buildings, C2 had a decrease in electricity use, three had about the same year-to-year use, and five increased their use of electricity by more than 5%. These increases ranged up to 24% with an average of 15%.

Energy use varied 10-fold, from 42-415 kWh/m<sup>2</sup> (Table 25), depending on whether the building was centrally air conditioned. For buildings with central air-conditioning (CAC), the range was 79-415 kWh/m<sup>2</sup>. However, the high figure for G2 occurred because a printing plant required heavy air-conditioning. Accordingly, this building is excluded in discussion of average energy use.

For the remaining seven centrally air-conditioned buildings, average estimated electricity use in 1982 was 151 kWh/m<sup>2</sup>, (range 79-209 kWh/m<sup>2</sup>; standard deviation 47 kWh/m<sup>2</sup>). Average use in 1982 was about 5% higher than in 1981 with an electricity bill about 13% higher.

(Until 1 July 1981, FEA had a declining block rate, which made it difficult to establish average rates. In CAC buildings, the air conditioner was on a separate account; for a monthly 50,000 kWh the average rate before July was 13.2 ¢/kWh. After 1 July, there was a flat rate of 15.75 ¢/kWh, giving an average for 1981 of 14.5 ¢/kWh, which would apply both to air conditioning and to elevators. Tenants who paid for lighting and equipment use generally consumed less than 3000 kWh/month; they would pay about 15.1 ¢/kWh for the first half of 1981, with an average rate for the year of 15.4 ¢/kWh. The survey showed that air conditioning and elevators accounted for 69% of the total electrical consumption of a building; this would place the average rate for the whole building at 14.7 ¢/kWh.)

Total electricity bills for the CAC buildings were estimated at FJD 48,400-238,000 for 1982. Non-CAC buildings were considerably cheaper to supply with energy, both absolutely (FJD 9000-14,000 less) and per square metre (FJD 7-19 less).

To ascertain possible reasons for the 1981-1982 increase in consumption, we studied weather data for January to May of each year. However, the average monthly daily maximum was the same, 30.3°C, for both 5-month periods. Average relative humidity was only slightly higher in the first 5 months of 1982 than in the same period of 1981 (82% against 81%), so weather can be discounted as a factor in the increase.

Discussions with owners and managers of buildings and maintenance contractors revealed that time clocks on the air-conditioning systems frequently malfunctioned, causing these systems to be operating for longer than intended. This was the cause for the large increases in consumption in buildings P1 and P2.

Because of malfunctioning controls, monthly use fluctuated widely in some CAC buildings, and this made it difficult to estimate annual consumption from the first quarter or half of a year. Thus, when the air conditioning was inoperable, as with G2, consumption was reduced. When it inadvertently ran 24 hours/day, as happened with P2, consumption was much higher. The annual use of electricity for

air-conditioning depends on how quickly malfunctions are noticed and corrected. Figure 20 summarizes estimates of energy use for the surveyed buildings, making allowances for months in which the CAC malfunctioned.

In June 1982, some office managers instituted energy-saving measures; thus, 1982 consumption was probably lower than our estimates.

We calculated electricity consumed for each use from the survey data on a building's equipment, rated wattage, hours of use, and assumptions or observations on load factors. The sum of these calculations should equal the consumption as recorded on electricity bills.

However, the survey only recorded building operations at one point in the year, which may not have been typical -- especially for air-conditioning. Accordingly, we held extensive discussion on hours of use and load factors with owners, managers, and maintenance contractors.

Table 26 breaks down calculated consumption by major uses in the 10 buildings. Central air-conditioning, in those buildings that had it, accounts for 55-83% of total use. Excluding G2, in which the air conditioning was for the benefit of equipment rather than the occupants, the calculated average annual cost per square metre of CAC buildings was FJD 24.20, of which air-conditioning accounted for 64%, lighting 19%, equipment 13%, and elevators 5%.

Thus, for a typical office building of 4000 m<sup>2</sup>, air conditioning would cost FJD 62,000/year or FJD 24.80/hour (based on 2500 hours/year), and lighting FJD 18,400 or FJD 7.36/hour.

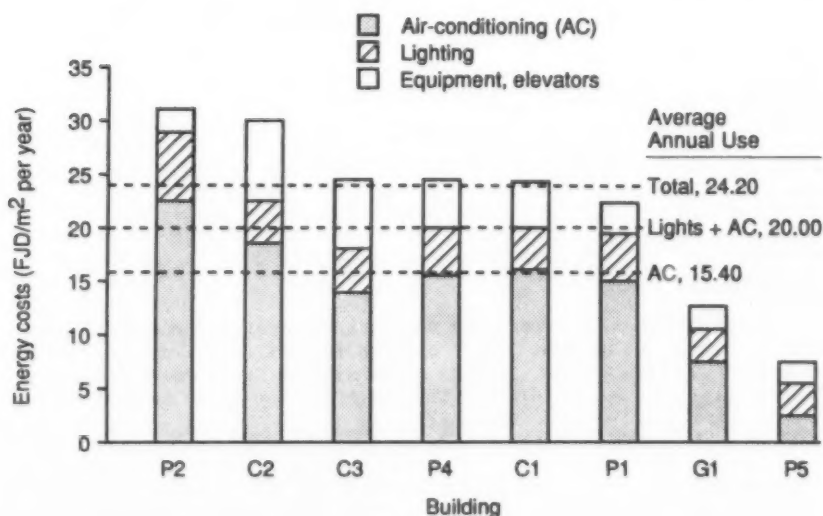


Fig. 20. Energy costs of eight typical office buildings in Suva, 1982. In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

The sample of two non-CAC buildings is too small to base any conclusions on regarding typical practice, although it can be said such buildings tend to be smaller and older. P3 has excessively high lighting levels and long hours of use. The cost of room air-conditioning for these buildings was similar at about FJD 2.70/m<sup>2</sup> per year. If lighting and equipment levels are taken as similar to those of CAC buildings, total electricity cost would be FJD 10.40/m<sup>2</sup>, or 55% less than in CAC buildings.

The consumption of energy by air conditioners depends on the equipment rating, hours of use and load factor (that is, the ratio of actual load to rated load). To make the calculations, we noted the equipment rating during the survey or obtained it from the maintenance contractor. Hours of use came from time clocks, if they were installed, or the building manager. If the building did not have time clocks, or if they were malfunctioning, there was no clear idea of how long the system was operating -- in the case referred to above, no one noticed that the system was running 24 hours/day until, after several months, the manager discovered the problem through the fuel bills.

We obtained the load factor by observing operating amperage on the control board and comparing it with the rating. Where no ammeter was available, we assumed a load factor of 0.7 for chillers and 0.8 for pumps and fans. Table 27 presents details on air-conditioning systems and use.

The wattage per square metre of office space of the CAC system was similar in all buildings, at about 36 W/m<sup>2</sup>, except in C2 and G2. In the former, there were three chillers installed with one on standby, so power output was low; in the latter there was excess installed capacity, as the low load factor shows. Indeed, both G1 and G2 had 20% overcapacity in view of the maximum expected load on a typical hottest day. Many CAC systems operated unnecessarily far more than normal office hours, say 0800 to 1640, about 2125 hours/year. C3 the largest building with the largest CAC system, has the lowest number of operating hours and the second lowest energy use per square metre.

Thus, there is plenty of scope for reducing air-conditioning consumption simply by reducing hours of operation through the installation of low-cost, effective time clocks. Building C2 has reduced its hours of CAC operation by 50% since June 1982, with the saving of FJD 4000/month. For G2, it is proposed to switch off the whole CAC system at times and some fan coil units altogether with some additional improvements for an estimated saving of FJD 8000/month. It costs nothing to switch off equipment.

Lighting levels, use and cost are shown in Table 28. Nearly all the lights were 40 W fluorescent tubes, which typically had a power consumption with ballast of 50 W (Dryden 1975:111). Energy use for lighting was modest in these buildings (except P3), with an average of 12 W/m<sup>2</sup>.

Except for G1 and G2, we calculated lighting use by multiplying the power rating of lights by stated hours of use. For G1 and G2, we multiplied the ratings by a load factor and then by the number of office hours. Office cleaning takes place generally after business hours, which is why hours of use exceed office hours, which normally are 2100 hours/year. However, for C2, hours of use seem greater than

Table 26. Commercial buildings annual consumption and costs<sup>a</sup>  
by end use, 1982.

|                                            |                    | Air-<br>conditioning | Lights | Equipment | Elevators | Total |
|--------------------------------------------|--------------------|----------------------|--------|-----------|-----------|-------|
| Buildings with central air-conditioning    |                    |                      |        |           |           |       |
| C1                                         | MWh                | 220                  | 52.6   | 44        | 13.6      | 330.2 |
|                                            | FJD 000            | 34.6                 | 8.3    | 6.9       | 2.1       | 52    |
|                                            | FJD/m <sup>2</sup> | 16.1                 | 3.84   | 3.22      | 0.99      | 24.1  |
| C2                                         | MWh                | 576                  | 127    | 195       | 36        | 934   |
|                                            | FJD 000            | 90.7                 | 20     | 30.7      | 5.7       | 147   |
|                                            | FJD/m <sup>2</sup> | 18.5                 | 4.08   | 6.26      | 1.16      | 30    |
| C3                                         | MWh                | 796                  | 271    | 185       | 154       | 1406  |
|                                            | FJD 000            | 125                  | 42.7   | 29.1      | 24.3      | 221   |
|                                            | FJD/m <sup>2</sup> | 13.84                | 4.72   | 3.22      | 2.68      | 24.4  |
| P1                                         | MWh                | 246                  | 80     | 40        | 0         | 366   |
|                                            | FJD 000            | 38.7                 | 12.6   | 6.3       | -         | 57.6  |
|                                            | FJD/m <sup>2</sup> | 14.8                 | 4.81   | 2.4       | -         | 22    |
| P2                                         | MWh                | 599                  | 189    | 34        | 15        | 837   |
|                                            | FJD 000            | 94.3                 | 29.8   | 5.4       | 2.4       | 131.8 |
|                                            | FJD/m <sup>2</sup> | 22.2                 | 7      | 1.26      | 0.56      | 31    |
| P4                                         | MWh                | 372                  | 107    | 65        | 54        | 598   |
|                                            | FJD 000            | 58.6                 | 16.9   | 10.2      | 8.5       | 94    |
|                                            | FJD/m <sup>2</sup> | 15.6                 | 4.49   | 2.73      | 2.27      | 25.1  |
| G1                                         | MWh                | 170                  | 83     | 43        | 15        | 311   |
|                                            | FJD 000            | 26.8                 | 13.1   | 6.8       | 2.4       | 49    |
|                                            | FJD/m <sup>2</sup> | 6.9                  | 3.39   | 1.75      | 0.61      | 12.7  |
| G2                                         | MWh                | 1358                 | 129    | 150       | 0         | 1637  |
|                                            | FJD 000            | 214                  | 20.3   | 23.6      | -         | 258   |
|                                            | FJD/m <sup>2</sup> | 54.2                 | 5.14   | 5.98      | -         | 65.3  |
| Buildings without central air-conditioning |                    |                      |        |           |           |       |
| P3                                         | MWh                | 40                   | 170    | 30        | 0         | 240   |
|                                            | FJD 000            | 6.3                  | 26.8   | 4.7       | -         | 37.8  |
|                                            | FJD/m <sup>2</sup> | 2.9                  | 12.5   | 2.2       | -         | 17.6  |
| P5                                         | MWh                | 20.3                 | 27     | 11.9      | 0         | 59.2  |
|                                            | FJD 000            | 3.2                  | 4.25   | 1.99      | -         | 9.3   |
|                                            | FJD/m <sup>2</sup> | 2.36                 | 3.14   | 1.38      | -         | 6.9   |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).

Table 27. Central air conditioning systems in commercial buildings.

|    | Rated<br>kW | Load factor      |                  | Time<br>in use<br>(hours/year) | Power<br>(W/m <sup>2</sup> ) | Usage              |              |
|----|-------------|------------------|------------------|--------------------------------|------------------------------|--------------------|--------------|
|    |             | Chillers         | Fans             |                                |                              | kWh/m <sup>2</sup> | kWh/occupant |
| C1 | 78          | 0.7 <sup>a</sup> | 0.8 <sup>a</sup> | 3000                           | 36                           | 103                | 1220         |
| C2 | 96          | 0.7              | 0.8              | 6000                           | 20                           | 118                | 2060         |
| C3 | 335         | 0.7              | 0.8              | 2375                           | 37                           | 88                 | 1770         |
| P1 | 98          | 0.4              | 0.6              | 2500                           | 37                           | 94                 | 1340         |
| P2 | 160         | 0.7              | 0.9              | 3750                           | 38                           | 141                | 1750         |
| P4 | 130         | 0.7 <sup>a</sup> | 0.8 <sup>a</sup> | 2860                           | 35                           | 99                 | 1630         |
| G1 | 152         | 0.3              | 1.0              | 2730                           | 39                           | 44                 | 890          |
| G2 | 372         | 0.3              | 0.7              | 8760                           | 94                           | 344                | 9063         |

<sup>a</sup> Assumed values.Table 28. Lighting levels, use, and cost<sup>a</sup> in commercial buildings.

|    | W/m <sup>2</sup> | Annual use         |              | FJD/m <sup>2</sup> | Hours per<br>year |
|----|------------------|--------------------|--------------|--------------------|-------------------|
|    |                  | kWh/m <sup>2</sup> | kWh/occupant |                    |                   |
| C1 | 8.2              | 24                 | 290          | 3.84               | 2800              |
| C2 | 6.8              | 26                 | 450          | 4.08               | 3800              |
| C3 | 12.0             | 30                 | 600          | 4.72               | 2500              |
| P1 | 12.2             | 31                 | 440          | 4.81               | 2500              |
| P2 | 18.4             | 44                 | 550          | 7.00               | 2400              |
| P4 | 13.4             | 29                 | 470          | 4.49               | 2100              |
| G1 | 10.1             | 22                 | 440          | 3.39               | 2100 <sup>b</sup> |
| G2 | 22.0             | 33                 | 860          | 5.14               | 2200 <sup>c</sup> |
| P3 | 21.5             | 80                 | 1550         | 12.50              | 3200              |
| P5 | 8.1              | 20                 | 340          | 3.15               | 2300              |

<sup>a</sup> In 1981, FJD 1 (Fijian dollar) = USD 1.1456 (United States dollar).<sup>b</sup> Load factor = 0.95.<sup>c</sup> Load factor = 0.70.

appropriate, being equivalent to 0600 to 2100, 5 days/week. With lighting costs averaging FJD 7.40/hour in a 4000-m<sup>2</sup> building, reduction of lighting by 2 hours/day would save FJD 3700/year.

New high-efficiency lights have been introduced by several companies and are available in Fiji. It is now possible to buy, at no extra cost, 36-W tubes with the same light output as the older 40-W tubes and a lower power ballast of 4 W. Over their lifetime (5000 hours), they save FJD 3/unit. A typical office building of 4000 m<sup>2</sup> holds the equivalent of 1300 of these units; replacing the old with the new would save FJD 3900 in 2 years.

Incandescent lights can be replaced with long-life, low-wattage tubes that give the same light output but use less power -- 18 W rather than 75 W. Over the 5000-hour life of the tube, the net saving in electricity and fixtures would be FJD 32. However, these lights have a low power factor (that is, the ratio of resistive power in kW to apparent power kVA); this in effect means that a consumer on maximum demand may not save anything with them.

It is difficult to make estimations for equipment and elevators, as assumptions are needed for load factors and hours of use. Calculations must take into account that the rated power on equipment is much higher than normal operating power. For refrigerators, a load factor of 50% was used, based on a preliminary survey of domestic refrigerators that the team carried out early in 1980. For computers, we assumed operating power was 95% of rated power operating 24 hours/day. We monitored the elevator in G1 for 3 months and decided on a load factor of 60%.

Office equipment is diverse and uses little energy, so it is difficult to reduce the energy they do use. For elevators, the hours of operation can be reduced and service suspended over weekends. Elevator service costs about FJD 2/hour in the typical (4000 m<sup>2</sup>) building, so only minor savings of less than FJD 1000/year are likely.

### Discussion

It would be useful to compare the use of energy in commercial buildings in Fiji with similar use in other countries. However, caution must be used in comparing buildings in different climates. For instance, in Fiji, about two-thirds of energy used in air-conditioning goes to reducing humidity, so temperature reduction cannot accurately indicate work done.

Thus, a study (Wheeler 1981) of the use of energy in office buildings in Papua New Guinea (PNG) is available, but a typical office building in PNG is not defined. Wheeler notes: "the greatest loads (often over half the energy consumption) are produced by the air-conditioning units. The loads generated by an air-conditioned high-rise office are of the order of 60-70 W/m<sup>2</sup>, with hotels being at the higher end of the range. Some office buildings in Port Moresby can generate a load of 100 W/m<sup>2</sup>."

In the survey of commercial buildings in Suva, the average load in CAC buildings was 49 W/m<sup>2</sup> with a range of 29-70 W/m<sup>2</sup>.

In the United States, the average energy consumption of existing buildings in 1980 was estimated by Harding (1981) at 194 kWh/m<sup>2</sup>. For buildings constructed in that year, Harding estimated 162 kWh/m<sup>2</sup>.

By comparison, Suva's office buildings in 1981 consumed an average 144 kWh/m<sup>2</sup>. However, the use of air-conditioning in U.S. commercial buildings is much lower in hours per year than in Fiji, although there is extensive heating. Lighting energy use in Suva was much lower at 13 W/m<sup>2</sup> than in the United States, where it was an estimated 22 W/m<sup>2</sup> or more in new construction in 1980.

Thus, rather than seeking to determine how efficient commercial buildings are in Suva by comparing them with those of other countries, it is better to examine how Suva buildings can be made more energy-efficient.

Of the 10 buildings surveyed, two were not centrally air conditioned and one was a print workshop in which air-conditioning was dictated by the needs of the processes and equipment rather than the needs of people. Thus, only seven buildings were available from which to draw conclusions about energy use in typical commercial buildings -- in this case, high-rise office buildings.

From the survey of these seven buildings, we calculated that air conditioning and ventilation account for 63% of total energy used. Lighting was the second major use at 19%, then equipment at 13% and finally elevator service at 5%. The annual cost of energy for these buildings was FJD 12.70-31.00/m<sup>2</sup> with an average of FJD 24.20. Thus, for a medium office building of 4000 m<sup>2</sup>, energy cost was nearly FJD 100,000.

The main opportunities for conservation lie in reduction of hours of operation of the air-conditioning system. The survey found many systems without effective time clocks, which meant that they were operating longer, at a cost of about FJD 6/hour per 1000 m<sup>2</sup>, than intended. Installation of time clocks has reduced operating hours in several buildings. The cost of installing them is minor compared to the savings they produce.

The appointment of someone responsible for energy use and conservation is the most important step building managers can take to reduce the use of energy. Such a person can monitor and plot energy use, identify irregularities, and hence determine the cause of excessive use.

An energy audit of the building is the next most important step, and this will reveal in detail where the energy is going and where it can be conserved. After the survey, proposed conservation schemes can be examined and the most cost-effective ones chosen. In general, savings of up to 10% can be achieved with little or no cost and savings of 10-25% can be accomplished with minor expenditure. Savings of about 25% frequently need some capital investment, but the return is well above the cost.

The Fiji Ministry of Energy and Mineral Resources hired a consultant to carry out an energy audit in August 1982 of the two government buildings we surveyed. In G1, in which electricity cost had been FJD 48,400/year, he recommended improvements costing FJD 12,000 that saved FJD 5800/year, thus yielding an annual return on the investment of 47%. The main improvement was installation of an automatic temperature control for the CAC system.

G2, the government printery, had had an electricity cost of FJD 258,000. The consultant recommended that parts of the central air-conditioning be no longer used at all and that all of it be used fewer hours. The net reduction of CAC use amounted to 30% and electricity savings were FJD 96,000/year for an investment of FJD 54,000 -- a 178% return.

There was a lot of scope for energy savings in some of the buildings surveyed; some of these measures either were already being put into effect or had been proposed by energy auditors. Below we present the costs and returns on some of the more important measures that can be taken; the costs are mostly one-time investment costs, but the returns are annual.

- Having an energy audit and report by an experienced auditor. Cost: about FJD 5000; possible savings: FJD 10,000-20,000.
- Appointing a staff member to monitor energy use, identify conservation options, implement recommended measures, educate and motivate staff, and ensure maintenance is carried out. Cost: up to FJD 10,000; savings as above.
- Reducing air-conditioning operation by 2 hours in the morning and 2 hours in the evening. Cost: nil; savings: FJD 6000/year for every hour per day reduction.
- Installing a 7-day time clock to control air-conditioning. Cost: FJD 200; savings as above.
- Resetting temperature controls from low twenties to 26°C and 70% relative humidity and installing tamper-proof line thermostat. Cost: nil for resetting, FJD 150 for new thermostat; possible savings: FJD 10,000-15,000.
- Installing a new automatic temperature control system. Cost: FJD 10,000; savings, FJD 5000/year.
- Installing room air conditioners and insulating the rooms that need cooling. Cost: FJD 2000-5000; savings: FJD 3000-5000.
- Switching off lights when not needed and having cleaning done during office hours. Cost: nil; savings: FJD 1800/year for every hour per day when lights off.
- Persuading cleaners to work on one floor at a time rather than on all floors at once. Cost: nil; savings: as above.
- Replacing old 40-W fluorescent tubes with 36-W tubes. Cost: nil; savings: FJD 1500.
- Replacing incandescent bulbs with fluorescent tubes. Cost: FJD 720/year; savings: FJD 2000/year.
- Rearranging light switches so each room has its own light switch. Cost: can be high for rewiring; savings FJD 2000-4000.
- Removing fluorescent tubes from fixtures near windows. Cost: nil; savings: up to FJD 2000.
- Removing some fluorescent tubes from fixtures in areas with low lighting requirements (such as corridors or lobbies). Cost: nil; savings: FJD 1000-2000.
- Borrowing or buying a light meter to check lighting levels. Cost: up to FJD 300.

- Having one staff member responsible for switching off equipment during lunch and after work. Cost: nil; savings: FJD 500-1000.
- Reducing or eliminating availability of hot water. Cost: nil; savings: up to FJD 2000.
- Installing time clocks on water heaters. Cost, FJD 150 each; savings: FJD 300-500.
- Reducing water temperature to 45°C. Cost: nil; savings: FJD 500-1000.
- Installing low-flow shower heads to reduce hot water in showers. Cost: FJD 25 each; savings: FJD 100-300.
- Switching off elevator at night and weekends. Cost: nil; savings: FJD 300-500.

## DISCUSSION AND CONCLUSION

### The Research Problem

As in most other developing countries, energy planning and energy policy formulation are relatively recent introductions into government functions in Fiji. They have followed in the aftermath of the world oil crisis of the early 1970s.

The task of planning any sector requires an understanding of the intricate workings of that sector. In the case of energy, a planner and policymaker needs to understand:

- ° the final end uses of energy in the total economy,
- ° the various conversion technologies employed at end use,
- ° the different forms of energy used,
- ° the different supplies of energy involved,
- ° the relative costs of production and supply of energy forms,
- ° the relative prices at which they are purchased,
- ° the efficiencies of use both within and between different energy forms,
- ° the potential alternative supplies available and conversion technologies feasible,
- ° the interaction between a specific energy form chosen or used, the socioeconomic structure of society, and the direction of development that results.

A new energy-planning department or even ministry, as was set up for Fiji in mid-1981, therefore, faces an enormous task of information gathering. Although some information is available, much of it is not compiled in convenient forms, while much is incomplete and could be misleading.

In Fiji, information on commercial energy supply and energy use in the commercial/industrial sector was relatively easier to collect. On the other hand, how noncommercial energy forms were utilized and what their supplies were like were much more difficult to grasp or quantify. In addition, the end use of energy in the household sector was largely unknown.

Just before the establishment of the Fiji Ministry of Energy, two special surveys were conducted that provided some information on noncommercial and household energy use in rural areas of Fiji. The

picture remained incomplete without similar surveys of energy end use in the different economic sectors of Fiji's urban communities.

A rural energy survey in 1978/79 found 92% of rural households used wood and estimated that Fiji's rural population used 506 kg/person per year (oven-dry weight) of wood. It predicted a shortage of firewood in specific locations within 5 years. Nothing was known of the use of wood in the more densely populated urban centres where 40% of Fiji's population lived. Similarly, although the consumption of kerosene for lighting was found to be substantial in rural homes, the extent of electrification of urban homes, their commercial energy consumption patterns, and the extent to which they might also depend on wood fuel was largely unknown.

The use of energy in the other sectors -- industry, commerce, and public services was not clear either.

Without the knowledge of how energy was being used and how much of it was being used for different purposes, it was not possible to plan for effective management of the energy sector.

It was clear that the need for information on urban energy use was urgent. Although the Bureau of Statistics publishes an annual industrial survey, the information collected on energy use is not sufficient to identify the relative importance of different end uses.

The planners needed to know:

- ° the different end uses and their relative importance,
- ° the different energy supplies, their costs/prices, and relative importance,
- ° the overall energy needs of the different sectors, and
- ° the opportunities for better management and for savings.

The survey reported here was designed to fill the information gap as much as was possible. The collection of data was hampered by the paucity of good records in the industrial and commercial establishments and the limitations of the interview/questionnaire method in the household sector.

Therefore, although the data collected and analysed in this report may not be as accurate as it could be with efficient record keeping, it is better than a situation where very much less existed. As rigorous a system as possible of checking the data collected was used.

These problems of methodology are explained further in the report.

### Conclusions and Recommendations

The survey was made only of the Suva urban area. The conclusions and recommendations of the research are, therefore, specifically applicable to Suva. However, concurrent with the survey reported

here, a similar survey was conducted in two other major urban centres of Fiji -- Lautoka and Nadi. The broad findings and conclusions of that survey echoed those of this one. Therefore, these findings could be assumed to provide an indication of overall urban energy use in the country.

The major conclusions, resultant recommendations, and follow-up government activities are given for three broad sectors -- transport, households, and industrial/commercial.

### **Transport**

Energy use for transport comprised the major end use for imported fuels in the urban centres and indeed at the national level. Although transport outside the premises of an industrial establishment was not investigated, and although the transport sector itself was omitted from the study, due to time and financial constraints, national figures and the household survey showed the great importance of the sector as a major end user of imported fuel. The consumption of motor spirit for privately owned vehicles was shown to be quite substantial.

The study recommended a detailed examination of public transport energy use and promotion of public education in transport energy savings.

Government has, since, launched a 3-year study program to investigate transport energy use. The 1st year's examination focused on the bus industry, the government fleets and the Fiji Sugar Corporation cane-transport needs. The 2nd year's study will focus on vehicle maintenance systems and public (including drivers) education. The 3rd year's study will establish the long-term policy and programs for managing energy use in the transport sector.

### **Households**

#### Kerosene Cookers

The widespread use of kerosene as a cooking fuel and the very common utilization of the multiwick cooker for kerosene cooking was expected but nevertheless still surprising. It was obvious that if any government action was to affect household kerosene consumption beneficially, then the quality of the very popular multiwick single-burner kerosene cooker must be examined. The development of a safer and more efficient kerosene cooker was considered urgent.

Government has, since the survey, worked closely with the Consumer Council of Fiji to monitor the use and abuse of kerosene cookers and to conduct a study on the safety of such cookers. A series of rigorous safety and materials quality tests have been planned.

#### Wood and Charcoal

A surprising proportion of urban households were found to use wood for cooking some if not all of their meals. Many of these were too poor to afford kerosene. Some, however, were beginning to have difficulties in securing free wood and had begun to purchase cheap supplies from timber mills.

The study concluded that it was important to examine current and potential supplies of wood for urban dwellers and concurrently to develop efficient wood-burning stoves for urban households. Charcoal cooking could also be promoted for those in crowded high-rise buildings where a wood-burning stove would be impractical.

The Fiji government has since promoted the development of a metal stove specifically for urban homes. The option of using the stove also as a water heater is available. Government has also begun the process of examining urban wood and charcoal supplies to begin a program for ensuring their sustainability.

### Electricity

The survey found a substantial absence of awareness of the savings possible in electricity use by household consumers. This was obvious for all the different end uses of electricity in the home. The need for repeated, simple, educational messages on household electricity conservation possibilities was obvious.

Widespread use of the public media, both through the papers and the radios, has been made by both the Government and the Consumer Council to increase people's awareness of energy conservation.

### Industrial/Commercial

Despite the aggressive profit-making orientation of Suva's private sector executives and management personnel, it was obvious to the study that most of them were unaware of potential savings (and, therefore, greater profit) through energy-conservation measures. It was obvious that the private sector had to be made aware of the benefits of good energy management.

Having been made aware, it was also obvious that they had to be helped through provision of free or subsidized auditing services, and provision of some assistance for financing the implementation of the recommendations of the audits.

Government has, since the study, begun a program of energy conservation comprising the following:

- \* A planned program of implementing energy-conservation measures in government premises, not only to reduce government energy expenses but also to serve as a demonstration to the private sector;
- \* A program of audits of selected private sector establishments as case studies;
- \* An occasional workshop for private sector personnel using the government examples and private sector case studies; and
- \* Investigations into the possibility of establishing a Third Party Financing Scheme to help private sector establishments implement good energy management measures.

This report is now being completed almost 5 years after the survey itself was conducted. The findings of the survey were conveyed

to the government decision-makers as soon as the results were analyzed after each sector was completed. Therefore, the utilization of the survey results and the implementation of the survey recommendations were possible before the completion of this final report.

It has been rewarding to know that much of what this survey found has added to the knowledge of the situation in Fiji and that the major recommendations of the study have been used to guide follow-up programs by the Fiji government.

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## APPENDIX

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